The Cuneiform bones make up front part of foot metatarsal Come in front of Cuboid & Cuneform bones.

Each little bone of toes big ones is called Phalanges Four outer toes have three Phalanges each. Big toe has two

all places where the bones touch each other called - Articulations

Big leg bone Rests on astragulus

Shape of Foot

Continued length where the metarsal

Get front part of the transverse arch called the anterior arch.

Right Pasture Leg
Coat.

Bones - Coat irregular surfaces
Outer part comes more in
contact than the center part.
Reason for a lot of bones in
Car correct balance. Variety
of movement.

Names of bones

Heal - Bone Calcaneum
another name of same
bone - Os - Calcis

Next in front of heal
bone - Cuboid bone

Next above heal bone
a little above & a little
inside - "Astragalus" Key Coat
heal bone

Next in front of" bone
a bone carrying the
inner border of foot
"Navicular" or "Scaphoid
Three little bones in
front of Scaphoid &
beside front part of
Cuboid - "Cuneiform

Legs made up of two
bones - Tibia - is
the main leg bone:
Outside a little behind is
the Fibula.
Leg bone rests on
Astragulus
Malleolus = Ankle
Bone.

Digitized by the Internet Archive
in 2026

https://archive.org/details/elementaryanatom0000mary

THE PHYSICAL EDUCATION SERIES

EDITED BY R. TAIT McKENZIE, M.D., M.P.E., LL.D.

FORMERLY MAJOR, ROYAL ARMY MEDICAL CORPS

PROFESSOR OF PHYSICAL EDUCATION AND PHYSICAL THERAPY, UNIVERSITY OF PENNSYLVANIA

PHILADELPHIA

ELEMENTARY ANATOMY AND PHYSIOLOGY

A TEXT-BOOK FOR STUDENTS IN HYGIENE AND PHYSICAL EDUCATION

BY

MARY REES MULLINER, M.D.

FORMERLY INSTRUCTOR IN THE SUMMER SCHOOL OF HARVARD UNIVERSITY; IN THE SARGENT SCHOOL FOR PHYSICAL EDUCATION; IN THE BOSTON SCHOOL OF PHYSICAL EDUCATION; AND IN THE DEPARTMENT OF HYGIENE, WELLESLEY COLLEGE; DIRECTOR OF THE AMERICAN SCHOOL FOR PHYSICAL EDUCATION

SECOND EDITION, THOROUGHLY REVISED

ILLUSTRATED WITH 309 ENGRAVINGS IN BLACK AND COLORS

LEA & FEBIGER

PHILADELPHIA

1928

Copyright
LEA & FEBIGER
1928

PRINTED IN U. S. A.

PREFACE.

In preparing the second edition of this book, the author has adhered to the original plan of compiling a text that should cover the essential facts that a student would be expected to learn in the first year of a course in hygiene. This includes a general view of the accepted facts of physiology and a more detailed description of the anatomy of the neuro-muscular mechanism, together with an abundance of the best illustrations.

While this volume is designed as a preparation, no attempt, therefore, is made to invade the domains of the more advanced subjects, such as kinesiology, physiology of exercise, physical diagnosis, physio-therapy, and personal hygiene, or to discuss the finer details of physiology that enter into a medical education.

Thanks are hereby rendered to such teachers as have made constructive criticism of the first edition of this work. Some of the improvements that were urged have been gladly made. Further helpful criticism is hoped for.

While it has been suggested that books designed for the laity should, so far as it is possible, avoid technical terms, to the writer this criticism has seemed misplaced. Inasmuch as students in hygiene, physical education and physio-therapy are preparing to enter the outskirts, as it were, of the medical profession, it is essential that they be drilled in the correct use of technical terms, not only for their own future satisfaction in reading, but that they may have a common ground of approach to physicians with whom they may collaborate. It is most disastrous, for the sake of fancied simplification, to use substitute terms or those that are imperfectly descriptive. It is far better to use terms whose significance is definite and universal among scientists than to make shift with a popular but erroneous term.

Little change has been made in the chapters on the bones, muscles and joints. Those on digestion and dietetics have been amplified, and a brief chapter on the reproductive system has been added.

While teachers would, naturally, use their own judgment as to the order in which they would present the various divisions of anatomy and physiology, it has seemed advisable to recast the chapter on the nervous system. By making three separate chapters, with that on the cerebrospinal division of the nervous system retaining its former position, *i. e.*, following the description of muscles, etc.; the cranial nerves and the organs of special sense allotted a chapter and the sympathetic system forming a third division, greater clarity is obtained. Following the chapters on the systems with which it is most intimately associated, *i. e.*, the circulatory, respiratory and digestive, the autonomic or sympathetic system logically seems best placed. This arrangement, it is hoped, will enable the student to better comprehend the subject as a whole and as related to the organism.

Acknowledgements and thanks are made to the authors consulted in preparing this text, namely, Gray, Gerrish and Morris in anatomy and Brubaker, Foster and Howell in physiology.

M. R. M.

Wellesley Hills, Mass., 1928.

EDITOR'S PREFACE.

ACCURATE knowledge of anatomy and physiology must always be the foundation on which physical training as well as the practice of medicine and surgery must rest.

Of good text-books on general anatomy we have an abundant supply, but the publication of this work will fill a long-felt want in the field of physical education. Up to the present time students have had to use the large general text-books, which include a great deal of material not of direct use to them, if they are to get the main facts of anatomy and physiology so necessary for their training.

No one could be better fitted to write such a text-book than Dr. Mary Rees Mulliner, both from her experience as a teacher and her training in physical education.

Her career goes back to 1890, as a pupil of the normal class in physical education of the Boston Y. W. C. A. In 1891 she took advanced work and reading with Jakob Bolin on mechanotherapy, a course which she followed up by private lessons and postgraduate work with Baron Posse. She graduated, in 1896, from the Boston University School of Medicine and practiced until 1913, specializing in mechanotherapy. From 1902 to 1913 she lectured at the Harvard Summer School on mechanotherapy and during the same period at the Sargent School on anatomy and mechanotherapy. She also gave instruction in anatomy and physiology at the Boston School of Physical Education in 1913–1914. At the opening of the American School of Physical Education, in 1914, anatomy was her subject. She was in charge of classes in war-reconstruction work under the Surgeon-General during 1918 and 1919, when she joined the department of hygiene at Wellesley College, in charge of corrective gymnastics.

To such a one the lack of a text-book in anatomy and physiology for students in physical education has been apparent from the first and has become more and more acute as classes have increased.

For the present work she has had the advantage of using many of the splendid plates contained in Gerrish's *American Text-book of Anatomy;* plates that for clearness and perfection are unequalled. She has successfully avoided the condensation of the quiz-compends which fail from lack of the necessary illustrations and explanation. The experience gained in the first edition has enabled the author to make additions and changes, greatly increasing its value to the readers for whom she writes. To students in physical education and to nurses a simple presentation of the essential facts of physiology and anatomy must accompany a careful selection of the information that will have the most direct bearing on their own problems. This work does not compete with the large general anatomies in use for medical students. It will be a valuable handbook, however, to lay the foundation for the more detailed discussion of muscular action and the physiology of exercise which would naturally follow it in a well-regulated course on physical education. It thus takes its rightful place early in this series of books written for the use of students who wish to build soundly their knowledge of the body and its education.

R. Tait McKenzie,
Editor

CONTENTS.

CHAPTER I.

Introduction.

Definitions 17
Names of Surface Parts 20
General Description of the Body 21
General Outlook on Relation of Parts of the Body 21
The Framework 22
The Food Purveyors 22
The Carrier Organs 23
The Waste Removers 23
The Organs of Motion 23
The Master Organs 24
The Reproductive Organs 25
Properties of a Living Body 25
The Cell 26
Differentiation of Cells 28
Aggregation of Cells 28
The Intercellular Substance 28
Questions 29

CHAPTER II.

The Tissues of the Body.

The Shape of the Cells 30
Connective Tissue 30
White Fibrous Tissue 31
Yellow Elastic Tissue 32
Areolar Tissue 32
Adipose Tissue 33
Gelatinous Tissue 34
Adenoid Reticular Tissue 34
Neuroglia 34
Cartilaginous Tissue (Hyaline Cartilage) 35
White Fibrocartilage 35
Yellow Fibrocartilage 35
Osseous Tissue 35
Dentinal Tissue 38
Epithelial Tissue 39
Membranes 40
Glands 41
Muscle Tissue 45
Striated Muscle 45
The Muscle Fiber 46
Plain or Non-striated Muscle Tissue 49
Cardiac Muscle Tissue 50
Nervous Tissue 50
The Neurons 50

The Liquid Tissue 52
The Plasma 52
Corpuscles, or Cells 53
Red Corpuscles (Erythrocytes) 53
White Corpuscle (Leukocytes or Lymphocytes) 55
Blood Platelets (Thrombocytes) 55
Functions of the Liquid Tissue as Related to Cells 56
Questions 56

CHAPTER III.

The Osseous System.

Structure of Typical Bone 57
Classes of Bones 57
Markings on Bones 58
Muscular Attachments on Bones 58
The Bones of the Skeleton 58
The Bones of the Skull 59
Frontal Bone 59
Parietal Bone 59
Temporal Bone 59
Occipital Bone 59
Sphenoid Bone 60
Ethmoid Bone 60
Malar Bones 61
The Bones of the Trunk 61
The Spinal Column 61
The Spine as a Whole 70
The Sternum 70
The Ribs 72
Peculiar Ribs 73
The Thorax 74
The Hyoid 75
The Upper Extremity 76
The Clavicle 77
The Scapula 78
The Humerus 80
The Bones of the Forearm, the Radius and the Ulna 84
Carpal and Metacarpal Bones 91
The Bones of the Lower Extremity 91
The Os Innominatum 91
The Ilium 91
The Ischium 94
The Os Pubis 95
The Pelvis 95
The Femur 96
The Patella 99
The Tibia 100
The Fibula 102
The Bones of the Foot 108
The Astragalus 108
The Calcaneum 108
The Cuboid 108
The Scaphoid 108
The Cuneiform Bones 108
The Metatarsal Bones 109
The Foot as a Whole 109
Questions 110

CHAPTER IV.

The Articulations.

Classes of Joints 111
The Articulations of the Vertebral Column . . 112
Articulations in the Upper Cervical Region . . 115
Articulations of the Thorax 115
The Articulations of the Upper Extremity . . 116
The Sterno-clavicular Articulation 116
The Scapulo-clavicular Articulation . . 117
The Shoulder-joint 118
The Elbow-joint . . 120
The Radio-ulnar Articulations . . . 122
The Wrist-joint . . 122
The Carpal Articulations 122
The Pelvic Articulations . . 123
The Sacro-iliac Synchondrosis . 123
The Symphysis Pubis . . 123
The Articulations of the Lower Extremity . 123
The Hip-joint 123
The Knee-joint 126
The Articulations of the Tibia and Fibula . 130
Ankle-joint 130
The Tarsal Articulations . . 131
The Relation of Muscles and Tendons to Joints . . . 133
Questions 134

CHAPTER V.

The Muscular System.

Ligamentous Action of Muscles 137
Tonicity of Muscles 137
Nervous Stimuli 137
Chemical Changes 138
The Naming of Muscles . 138
Movements of Muscles . 138
Methods of Study . . 139
Movements of the Segments of the Upper Extremity . 140
The Muscles Moving the Shoulder . . 141
Trapezius 141
Levator Scapulæ . . 142
Rhomboideus Minor . 143
Rhomboideus Major . 143
Serratus Magnus . 144
Pectoralis Minor . 144
Subclavius 144
The Muscles Moving the Arm . . 144
Deltoideus 144
Supraspinatus . . . 145
Pectoralis Major . . 146
Coraco-brachialis . 147
Latissimus . . . 147
Teres Major . . 148
Infraspinatus . 149
Teres Minor . . 149
Subscapularis 149
The Muscles Moving the Forearm . 149
Biceps Flexor Cubiti . . . 149
Brachialis . . . 150
Brachio-radialis . . . 152
Triceps Extensor Cubiti . 152
Anconeus 152

The Muscles Moving the Outer Part of the Forearm 152
Pronator Teres 152
Pronator Quadratus 152
Supinator 154
The Muscles Moving the Whole Hand 154
Flexor Carpi Radialis 154
Palmaris Longus 154
Flexor Carpi Ulnaris 154
Extensor Carpi Radialis Longus 156
Extensor Carpi Radialis Brevis 156
Extensor Carpi Ulnaris 156
The Muscles Moving the Fingers 156
Flexor Sublimis Digitorum 157
Flexor Profundus Digitorum 157
Flexor Ossis Metacarpi Minimi Digiti 160
Flexor Brevis Minimi Digiti 160
Lumbricales 160
Extensor Communis Digitorum 160
Extensor Minimi Digiti 160
Extensor Indicis 160
Abductors and Adductors of the Fingers 161
The Muscles Moving the Thumb and its Metacarpal Bone 162
Flexor Ossis Metacarpi Pollicis 164
Flexor Brevis Pollicis 164
Flexor Longus Pollicis 164
Extensor Ossis Metacarpi Pollicis 164
Extensor Brevis Pollicis 164
Extensor Longus Pollicis 165
Abductor Pollicis 165
Adductor Pollicis 165
The Muscles of the Lower Extremity 165
Movements of the Thigh 165
Movements of the Leg 165
Movements of the Foot 165
Movements of the Toes 166
The Muscles Moving the Thigh 166
Psoas Magnus or Major 166
Iliacus 166
Gluteus Maximus 166
Tensor Fasciæ Latæ 167
Gluteus Medius 168
Gluteus Minimus 168
Adductor Magnus 169
Adductor Longus 170
Adductor Brevis 170
Adductor Gracilis 171
Pectineus 173
Obturator Externus 173
Obturator Internus 173
Pyriformis 173
Gemellus Superior and Inferior 173
Quadratus Femoris 173
The Muscles Moving the Leg 174
Sartorius 174
Biceps Flexor Cruris 174
Semitendinosus 174
Semimembranosus 174
Popliteus 175
The Quadriceps Femoris 175
Rectus Femoris 175
Vastus Lateralis 175
Vastus Medialis 175
Vastus Intermedius 175

The Muscles Moving the Foot 176
Tibialis Anterior 177
Peroneus Tertius 177
Tibialis Posterior 177
Gastrocnemius 177
Soleus 177
Plantaris 180
Peroneus Longus 180
Peroneus Brevis 181
The Muscles Moving the Toes 181
Flexor Longus Hallucis 181
Flexor Brevis Hallucis 182
Flexor Longus Digitorum 182
Flexor Accessorius 183
Flexor Brevis Digitorum 184
Flexor Brevis Minimi Digiti Pedis 184
Lumbricales 184
Extensor Proprius Hallucis 185
Extensor Longus Digitorum 185
Extensor Brevis Digitorum 186
Abductor Hallucis 186
Abductor Minimi Digiti Pedis 186
Interossei Dorsales Pedis 186
Interossei Plantares 186
The Muscles of the Trunk 187
The Muscles in the Third Layer of the Back 187
Serratus Posterior Superior 187
Serratus Posterior Inferior 187
Splenius Capitis 187
Splenius Cervicis 187
The Muscles in the Fourth Layer of the Back 188
The Muscles in the Fifth Layer of the Back 191
Suboccipital Muscles 192
The Muscles of the Abdomen 192
Rectus Abdominis 192
Pyramidalis 192
Obliquus Externus Abdominis 193
Poupart's Ligament 193
Obliquus Internus Abdominis 194
Transversalis Abdominis 195
Quadratus Lumborum 196
The Muscles of the Thorax 196
Diaphragm 196
Intercostales 197
Levatores Costarum 197
Triangularis Sterni 197
Subcostales 197
Scalenus Anterior 198
Scalenus Medius 198
Scalenus Posterior 198
The Muscles of the Head and Neck 199
Sterno-cleido-mastoideus 199
Platysma 200
Muscles of Expression 200
Muscles of Mastication 202
Grouping of Muscles According to Function 202
Muscles Acting on the Head 202
Muscles Acting on the Spinal Column 202
Muscles of Respiration 203
Muscles Acting on the Shoulder-girdle 203
Muscles Acting on the Arm at the Shoulder-joint 203
Muscles Acting on the Forearm 203
Muscles Acting on the Hand at the Wrist 212

Grouping of Muscles According to Function—
Muscles Acting on the Fingers 213
Muscles Acting on the Thumb 213
Muscles Acting on the Pelvis 213
Muscles Acting on the Thigh at the Hip-joint 213
Muscles Acting on the Leg at the Knee-joint 213
Muscles Acting on the Foot at the Ankle-joint 214
Surface Outlines of Muscles . . . . . 204 to 214
Questions 214

CHAPTER VI.

General Consideration of Bursæ and Fasciæ.

Bursæ in Relation with the Shoulder-joint 215
Bursæ in Relation with the Elbow-joint 215
Bursæ in Relation with the Knee-joint 216
Bursæ in Relation with the Ankle-joint 216
The Fasciæ 216
The Fasciæ Lata 217
Annular Ligaments of the Ankle 218
Plantar Fascia 220
Connection of Fasciæ and Veins 220
Questions 220

CHAPTER VII.

The Nervous System.

General Consideration of the Brain, Including some Special Centers . . 221
The Encephalon 221
The Cortex 224
The Corpus Callosum 226
The Cerebellum 228
The Pons Varolii or Bridge of Varolius 228
The Medulla Oblongata 229
The Decussation of the Pyramids 230
Functions of the Cerebrum 231
Areas of the Brain, Motor and Sensory 232
Reflexes 233
Functions of the Cerebellum 236
Functions of the Medulla 236
The Blood Supply of the Brain 236
The Circulation in the Brain 237
Cerebral Work 237
Sleep 237
General Consideration of the Spinal Cord with Motor and Sensory Paths 238
The White Matter of the Cord 239
The Gray Matter of the Cord 239
Ventral Horns 239
Dorsal Horns 240
White Fibers of the Cord 242
Functions of the Spinal Cord 242
Conduction 242
Association and Augmentation 243
Transference 243
Reflex Action 244
Reflex Arc 244
Knee-jerk or Patellar Tendon Reflex 244
Ankle Clonus 244
Heart Reflex 244
Special Centers 244
Coördination and Automatic Action 244

The Cerebrospinal Nerves and Plexi 245
The Spinal Nerves 245
The Cervical Plexus 249
The Brachial Plexus 249
The Lumbar Plexus 257
The Sacral Plexus 259
Questions 260

CHAPTER VIII.

The Cranial Nerves and the Organs of Special Sense.

The Cranial Nerves 261
The Organs of Special Sense 262
The Optic Nerve and the Eye 262
Accommodation 263
The Auditory Nerve and the Ear 265
The External Ear 265
The Middle Ear 266
The Internal Ear 266
The Gustatory Nerve and the Tongue 267
The Olfactory Nerve and the Nose 267
Nerves of Touch and General Sensation 268
Questions 270

CHAPTER IX.

The Circulatory System.

The Anatomy of the Heart 271
The Pericardium 271
Columnæ Carnæ 273
Valves of the Heart 273
The Anatomy of the Arteries 274
Divisions of an Artery 275
The Anatomy of the Capillaries 276
The Anatomy of the Veins 277
The Anatomy of the Lymphatics, Including Glands (Nodes) 277
The General Circulation of the Blood 278
The General Arrangement of the Arteries 280
Divisions of the Pulmonary Artery 280
Divisions of the Aorta 281
Carotid Arteries 286
Subclavian Artery 287
The Axillary Artery 287
The Thoracic Aorta 290
The Abdominal Aorta 290
The General Arrangement of the Veins 290
Systemic Veins 290
The Portal Vein 290
Superficial Veins of the Upper Extremity 291
Superficial Veins of the Lower Extremity 293
Long Saphenous Vein 293
Short Saphenous Vein 293
The General Arrangement of the Lymphatics and the Nodes 293
The Thoracic Duct 294
The Physiology of the Circulation 296
Systole and Diastole 296
The Cardiac Cycle 296
Apex Beat 297
The Pulse 297

The Physiology of the Circulation—
Steadying the Output of the Heart . . . 297
Arterial Recoil and Tension . . . 297
The Suction Pump . . . 298
Quantity of Blood in Body . . . 299
The Vasomotor Nerves . . . 300
The Nerve Supply to the Heart . . . 300
The Work of the Lymph . . . 301
The Work of the Red Corpuscles . . . 301
The Work of the White Corpuscles . . . 301
The Blood as a Carrier . . . 302
Coagulation of the Blood, or Clotting . . . 302
Questions . . . 302

CHAPTER X.

The Respiratory System.

The Organs Concerned in Respiration . . . 304
The Nose . . . 304
The Posterior Nares . . . 305
The Pharynx . . . 305
The Larynx . . . 305
The Epiglottis . . . 305
The Trachea . . . 307
The Bronchi . . . 307
Alveoli . . . 308
The Lungs . . . 309
The Mediastinum . . . 309
The Thorax . . . 311
The Mechanism of Respiration . . . 312
Types of Respiration . . . 313
Ratio of Rate of Respiration, Pulse and Temperature . . . 313
Sounds of Respiration . . . 313
Relation of Respiration to Circulation . . . 313
Intrathoracic and Intrapulmonary Pressure . . . 313
Intra-abdominal Pressure . . . 314
The Relation of Respiration to Abdominal Functions . . . 314
Pulmonary Capacity . . . 315
Vital Capacity . . . 315
Residual Air . . . 315
Tidal Air . . . 315
Complemental Air . . . 315
Supplemental Air . . . 315
The Composition of Inspired and Expired Air . . . 315
The Exchange of Oxygen and Carbon Dioxide . . . 316
The Innervation of the Respiratory Movements . . . 317
Questions . . . 317

CHAPTER XI.

The Digestive System.

The Composition of the Body . . . 318
The Composition of Foods . . . 319
Water . . . 319
The Inorganic Compounds . . . 319
The Organic Compounds . . . 320
Proteins . . . 320
Carbohydrates . . . 321
Fats . . . 322
The Need for Repair and Replacement of Materials . . . 322

The Processes in Converting Food into the Human Organism 322
The Chemical Changes in Digestion 323
The Organs Concerned in Digestion. The Alimentary Canal and Accessory Organs 325
The Mouth 325
The Teeth 325
Parts of a Tooth 328
The Uses of the Teeth 328
The Tongue 329
Salivary Glands 329
The Tonsils 330
Deglutition 332
The Esophagus 332
The Abdominal Cavity 332
The Stomach 334
The Coats of the Stomach 335
Gastric Glands 336
Gastric Juice 336
Gastric Digestion 336
The Small Intestine 338
Coats of the Small Intestine 339
Villi 339
Crypts of Lieberkühn 341
Lymph Nodules 341
The Duodenum 341
Intestinal Digestion 342
Movements of the Small Intestine 343
Accessory Organs of the Digestive Tract 344
The Liver 344
The Lobule 345
Gall-bladder 347
The Pancreas 347
Absorption 350
The Large Intestine 350
The Feces 352
Intestinal Fermentation 352
Blood Supply of the Intestines 353
Nerve Supply to the Intestines 353
Questions 354

CHAPTER XII.

Dietetics, Nutrition and Animal Heat.

Classes of Food and How Digested 355
Requisites of a Diet 357
Vitamins 358
Roughage 359
Metabolism 359
Basal Metabolism 360
Protein Metabolism 360
Fat Metabolism 361
Carbohydrate Metabolism 361
Animal Heat 362
Body Temperature 363
Questions 364

CHAPTER XIII.

The Organs of Excretion and Elimination.

The Kidneys 365
The Blood Supply of the Kidney 366

The Kidneys—
The Glomeruli . . . 366
Uriniferous Tubules . . . 367
Mechanism of the Formation of Urine . . . 367
The Urine . . . 368
The Nerve Supply of the Kidneys . . . 369
The Bladder . . . 369
The Skin . . . 370
Sweat Glands . . . 372
Sebaceous Glands . . . 373
Nails . . . 373
Epidermis . . . 373
Functions of the Skin . . . 373
Questions . . . 373

CHAPTER XIV.

The Sympathetic or Autonomic Nervous System.

Location and Arrangement . . . 375
The Vertebral Ganglia . . . 375
Solar Plexus . . . 376
Rami Efferentes . . . 376
Relation of the Sympathetic System to the Functions of the Body . . . 377
The Subconscious Mind . . . 380
Questions . . . 380

CHAPTER XV.

The Ductless Glands.

The Spleen . . . 381
The Endocrine System . . . 382
The Thyroid . . . 382
The Parathyroids . . . 383
The Thymus Gland . . . 384
Adrenal Gland . . . 384
The Pituitary Body or Hypophysis . . . 384
The Pineal Body or Epiphysis . . . 385
The Gonads . . . 385
Questions . . . 385

CHAPTER XVI.

The Reproductive System.

Puberty . . . 386
In the Boy . . . 386
In the Girl . . . 386
Generative Organs . . . 386
In the Male . . . 386
In the Female . . . 387
Menstruation . . . 389
Menopause . . . 389
Pregnancy . . . 389

ANATOMY AND PHYSIOLOGY.

CHAPTER I.

INTRODUCTION.

In hygiene, both public and personal, the fundamental studies are anatomy and physiology. This is also true in the study of physical education, nursing, physiotherapy and efficient living in general. Before the significance of the above subjects can be understood, the structure, relations, mechanisms and uses of the various parts of the body must be known.

It is not, however, necessary to go into all the minute details of anatomy and physiology to appreciate the wonderful way in which we live, move and have our being. A somewhat general and elementary view will serve to open the subject and possibly to interest some students to go more deeply into it.

Definition.—*Anatomy* may be defined as the science that treats of the structure of organized beings. Organized refers to that which has distinct and different parts as compared with those that are all alike. Metals, minerals and chemical substances in general are inorganic. Plants and animals have organs, which are essential parts, no matter how few and simple they may be. *Animal anatomy*, or *zoölogy*, includes the structure of human beings and of the lower animals, as distinguished from that of plants or *botany*. The subdivisions of zoölogy are called *human anatomy* and *comparative anatomy*.

Physiology refers to the study of the functions of the organs in animals.

The study of anatomy doubtless goes back to the infancy of the race. Every child is curious as to how things are made, and with adults the natural horror of death would be overcome by the desire to see what was inside the skin of a dead body. As bodies were examined, the various parts were given names, many of which survive to this day.

These names are not always properly descriptive, as might have been the case if the parts were to be named in the present state of knowledge. They were often given on account of a fancied resemblance to familiar objects, as in calling the cavity in which the

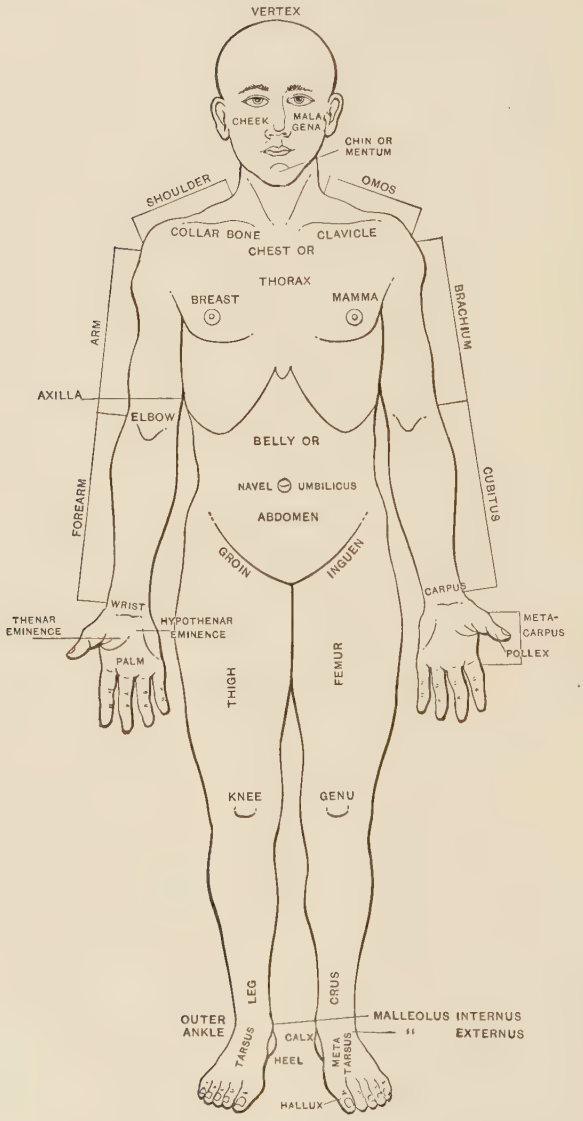


FIG. 1.—English names on left side. Latin names on right side.

head of the femur rests, at the hip-joint, the *acetabulum* or vinegar cup, etc.

When some individual studied and described a part, that had not been known before, the name of that person was tacked on, as *Eustachian canal, Poupart's ligament,* etc.

These methods make it difficult sometimes to give a reason for

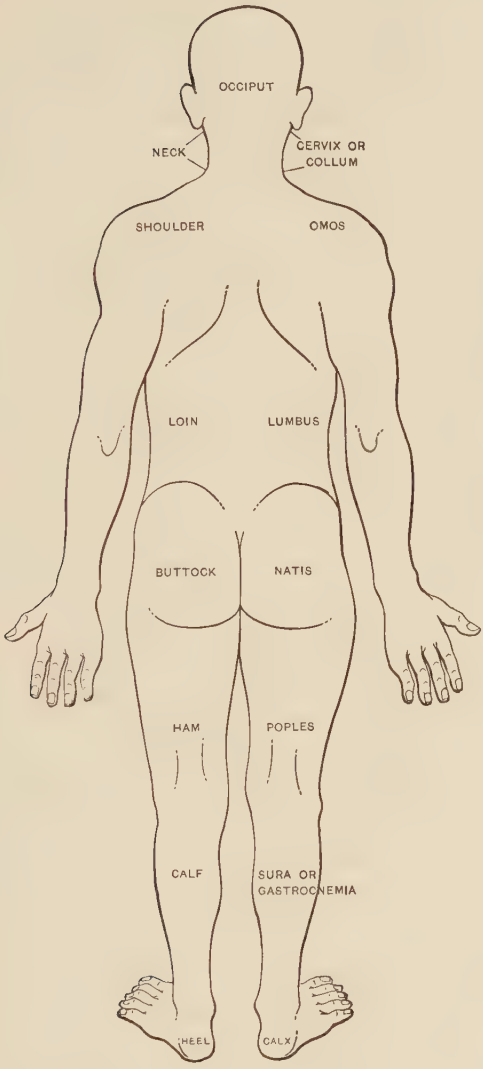


FIG. 2.—English names on left side. Latin names on right side.

terms, so we must fall back on the statement that certain parts are called in a certain way because they always have been so called.

In beginning the study of human anatomy, it is a great help to utilize the lower animals. Specimens from the bodies of cats, chickens, lambs, etc., are invaluable in studying the tissues, as they are identical in appearance and structure with those in the human

animal. Even the viscera of the cat bear a sufficient resemblance to those of man to form a most useful preliminary study.

Anatomy is studied either as the gross structures present themselves or with the help of a microscope in prepared sections. This latter method is called *microscopical anatomy* or *histology.* The study of the relations of one part to another is called *regional* or *relational* anatomy. Considering the body as made up of organs, its study is called *systematic* or *descriptive* anatomy; or it may be considered with regard to the needs of the surgeon or physician, as *surgical* or *medical* anatomy. *Pathological* anatomy treats of the diseased states of the body and the structural changes produced. *Artistic* anatomy interests the artist, while *applied* anatomy is essential to the work of the student in physical education.

The dissection of a body, that is, the careful cutting apart of its various structures is essential to a study of its make-up. The use of the roentgen rays is a modern development in scientific study and has the advantage of showing some things that cannot be seen except during life.

Physiology is studied by inference from dissections, by observation in the living body and more especially by experimentation on animals and human beings.

The parts of the body are given technical names, mostly Latin, and have also popular or vernacular names, which may carry a different meaning. To a layman, *leg* refers to the entire lower extremity, but to a medical person, it means the segment between the knee and the ankle, only. In the use of anatomical terms care should be taken that they be scientifically correct, even at the risk of seeming pedantic. And, they should be spelled correctly!

Names of Surface Parts.—The *anatomical position,* or that in which the body is studied, is supposed to be standing, with the arms at the side, and the palms of the hands facing forward. (Figs. 1 and 2.)

In that position, it is possible to consider the body as being divided by three planes. The *sagittal,* a vertical cut through the middle from front to back, dividing the body into right and left halves. The *coronal* or *frontal,* a vertical cut from one side to the other side, which divides the body into anterior or ventral, and posterior or dorsal parts. The *transverse* or *horizontal* section, which is on a level with the horizon, and may be made at any height.

Much of the relation of various parts has been learned by study of frozen sections.

A sagittal plane is a mesial plane, and descriptions of parts refer to their relation to that middle line, or plane. Toward it is mesial or medial; away from it is lateral.

Dextral refers to the right side, while sinistral refers to the left.

The transverse planes divide superior or upper parts from inferior

or lower ones. Proximal refers to that which is nearer the medial or the superior part, while distal has the opposite meaning.

General Description of the Body.—The *caput* or *head* is divided into the *cranium* and the *face*. Subdivisions of the cranium are the occiput at the back, the forehead in front, the sinciput at the vertex, and the temples at the sides. The face includes the chin, cheeks, nose, eyes and mouth. Below the head is the neck (*cervix* or *collum*), which connects it to the trunk. The front is called the throat, and the back of the neck, the nape (*nucha*).

The *trunk* is divided into the upper portion or chest (*thorax*) and the lower portion or belly (*abdomen*). The line of demarkation between the two is the lower border of the ribs and the lower end of the sternum, on the surface. Within, the floor of the thorax and the roof of the abdomen is formed by the diaphragm, a dome-shaped muscle. As this dome projects into the upper cavity, the thorax is smaller than appears on the surface, and the lower cavity is much larger.

On the chest is a rounded mound, called the *breast* or *mamma*, much more pronounced in women than in men. About the middle of the abdomen is a puckered depression, called the *navel* or *umbilicus*.

Projecting from the trunk are two upper extremities and two lower. The upper extremity presents four segments, in the following order; shoulder, arm, forearm and hand. Separating these are the shoulder-joint, the elbow-joint and the wrist-joint, in the order from above downward.

The lower extremity also presents four segments; hip, thigh, leg and foot. These are separated by the hip-joint, knee-joint and ankle-joint in the order from above downward. The hip serves as a part of the wall of the abdomen, while posteriorly on the same level, is a rounded mass of muscle and fat called the buttock (*natis*). Back of the knee-joint is a lozenge-shaped space called the ham (*poples*), with the cords or tendons on the inner and outer sides known as the *hamstrings*.

By reference to Figs. 1 and 2, other details of surface parts may be seen, with their English and Latin names.

GENERAL OUTLOOK ON RELATION OF PARTS OF THE BODY.

The body may be considered from many standpoints; as the temple of the soul; as a machine for doing work; as a laboratory where many materials are changed in form and chemical composition and adapted for further uses, and as a servant of the mind and will. It is all of these and more, and the knowledge of its whole and its parts will repay the hours necessarily spent in the study of anatomy and physiology.

The more one knows about the body, the more wonderful it seems, and the more inexcusable is ignorance of its marvellous adaptation to our needs.

It may sound paradoxical but it is true, that to get the best results from this study, one needs to know it all beforehand: in other words, the various parts are so interrelated to every other part that to comprehend the first part studied a knowledge of every other part is needed. The study of the muscles is bound up with that of the nerves, bloodvessels, etc. After all the divisions have been studied the student is ready to start again and really learn something. To help in getting a general view of the functions of the body, a brief account will be given here as a preliminary to more detailed work later.

The Framework.—If the body is a temple, there must be a framework upon which the various structures may be placed for support. The most noticeable part of this framework is the bony skeleton, which is encased by many other structures, holding them so they do not interfere with others equally important. The bones form cavities which contain and protect the brain, spinal cord, abdominal and pelvic organs, heart and lungs, etc., besides giving attachment to muscles and providing leverage for their action, with consequent movement of the various segments of the body. It is not the bones alone that constitute a framework. Fibrous tissue is everywhere in the body, serving this mechanical use. The individual cells, even of microscopical size, are resting in a fibrous network and if every other structure of the body were removed except the framework tissue there would be no perceptible change in its outward form.

Organs that have to do with the laboratory work in the body must be supported as a whole and in their parts by fibrous tissue, the bloodvessels must have a frame work and the nerves especially need protection and support.

The Food Purveyors.—A temple and a machine for doing work alike must have building material for new construction and for repair of broken-down parts, and as raw material for the peculiar kind of work done. The body does much mechanical work such as moving; it does chemical work in the production of heat and energy; it transforms and elaborates materials into various other forms. These materials thus used, are provided from outside the body in the form of food. An elaborate system, the digestive organs, is concerned in preparing this food so the various cells may take it in and make it of use. This process means mechanical preparation such as grinding and mixing; it means the formation of chemical reagents from the blood which act upon the food, utterly changing it in form and texture so that it may become fit to be used as building material, etc. Some of the organs so concerned are the teeth, stomach, intestines, liver, pancreas, etc., forming a long tube

with accessory laboratories. Another element, oxygen, is needed in the blood and that is provided by means of the respiratory system which brings the oxygen of the air into the body.

The Carrier Organs.—After the food is prepared to become a part of the tissue cells it must be taken around to them, so a system of tubes, called bloodvessels furnishes the roadway, while two pumps, one a force pump, the other a suction pump, cause the blood to be carried to all parts of the body, even to the microscopical cells. The tubes vary in size from 1 inch in diameter to those too small to be seen with the naked eye. No part of the body is without them. The food materials are thus carried to the various cells where they become a part of its structure, and are used to produce energy in the form of heat or motion, substances for the digesting of other food, and the formation of numerous other things needed in the body.

The Waste Removers.—In the blood carried by the tubes are not only the products from the food but the débris that results from the working of the body, or what is called waste material. These latter are taken up by the so-called organs of excretion, such as the skin, kidneys, liver, bowels and lungs, and cast out of the body, as otherwise it would be poisoned by them. At no time is the blood free from these waste materials, but if the organs work normally the amount is kept below the danger point.

The organs that remove this waste have two kinds of material to handle. First, there is the carbon dioxide which is produced during the combustion of carbon in the tissue cells.

In a stove, when carbon in the form of coal is burned, heat is given off, as well as gas (carbon dioxide), and there is a residue of ashes. When carbon is burned in the body, during the working of the cells, heat or some other form of energy results, and carbon dioxide, which is poisonous to the body, is given off and must be removed. The lungs provide the means for this. Secondly, other elements, among which is nitrogen, are broken down and cast out during the working of the cells. These waste materials are called "nitrogenous," though many other elements are included. They are acted upon by liver, skin, kidneys and bowels. By the activity of these organs the blood may be said to be purified.

The Organs of Motion.—If we consider the body as the servant of the mind it is evident that many forms of motion are necessary. One walks, runs and uses the arms and hands for a thousand different occupations. The muscles are these organs of motion, carrying out the orders of the mind. They are attached to the bony framework and move it. The muscles are intimately associated with the carrier organs, helping to form the suction pump which is concerned in moving the blood stream. They require a large supply of blood, and develop much heat and waste material. But they are quite

useless without the nerves which carry to them the orders from the brain.

There is other motion going on in the body, however, than that which is under the orders of the will.

In the walls of the bloodvessels, in the walls of the stomach and intestines, in the heart itself and in the skin, etc., are muscles that cause rhythmic movements by their contraction and so help carry on the functions of these parts as well as of all others. These contractions are regulated according to the needs of the tissues, under stimuli regulated by the subconscious mind, and they determine how much blood shall go through a vessel at any time, how much bile shall be secreted, how much perspiration shall come out on the skin, how regular the heart action shall be, and with what degree of energy the various functions of the body shall be carried on.

The Master Organs.—Every large business requires a directing head, and the human body is in the same case. The great central authority is the brain, the seat of the mind and will. From here, orders go out to and messages come in from all parts of the body. Numberless branches or nerves carry these impulses, so that there is no part of the body that cannot communicate with the brain.

The muscles are powerless without the nerves, and the will is impotent if the muscles cannot obey.

In addition to the brain, there is a part of the nervous system which must activate the body cells that have to do chemical work, such as secreting gastric juice, saliva, etc. This is called the sympathetic system, and it is the go-between for the subconscious self and the tissues, or the physical representative for what has never been definitely determined to have a local habitation. This system of nerves is widely distributed, but the greatest masses are in the abdominal cavity, and are known as the *solar plexus*, the *renal and aortic plexi*, etc. Smaller aggregations are in front of the spinal column. The name "abdominal brain" is sometimes given to this part of the master organs, but it is not fully descriptive. We know little of how to affect this system, but there is, without doubt a close relationship between the conscious mind and that which regulates this other essential part of living. Another set of organs that may well be classed as among the "master" organs, are the so-called "ductless" glands. Much remains to be discovered about these glands which secrete peculiar materials from the blood, and then let them go back into it. Or, which might be said to act as laboratories making most potent products, in secrecy, and then putting them back into the stream of raw material. The secretions have a wonderful influence upon the growth and development of body and mind, and exert powers of which the extent is, at present, unknown.

The Reproductive Organs.—The adult animal is provided with organs that have to do with perpetuating the species. These distinguish the male and female, and while present at birth, they do not develop into functional maturity until about the thirteenth year. Secretions from these organs are apparently necessary for the proper development of the entire organism during the years of adolescence, or from the age of twelve to twenty-five years. Diseased conditions of these organs have a far-reaching effect upon mind and body.

PROPERTIES OF A LIVING BODY.

The principal facts in anatomy have been obtained by the study of the cadaver or dead body, but those of physiology have been learned from the living body.

There are similarities between these two, but some essential differences which should be considered here.

First, in the matter of consciousness. The dead body has absolutely no consciousness of its surroundings, and at times a living body seems equally so. A person in a faint is oblivious to everything about him, but sooner or later he comes out of the faint and is more or less conscious of what is going on about him. So, a living body is said to possess more or less consciousness.

The living body may feel cold, but it is not of the same temperature as its surroundings, which does characterize the dead body. A temperature of 30° F. in the surrounding atmosphere would freeze a dead body, so it would register the same. But, the living body would maintain a relatively high temperature under the same conditions, and would register about 98° F. This would be no more if the surrounding temperature went to 110° F. The temperature of the living body would not go up to correspond, but would remain at the normal.

We may command the dead body to move, but it neither hears nor obeys. We may use electrical stimulation but no response is obtained. The body remains perfectly inert. But even when the living body is unconscious it still possesses the *power* of movement, of spontaneous movement, and it will respond to electrical and other stimuli.

These properties of the living body imply the power to adjust itself to its surroundings. Life has been defined as the continuous adjustment of one's self to his surroundings. It is not a poor definition from the standpoint of physiology.

The essential properties which enable the body to do this may be described in anatomical terms as—

1. Irritability, or the power to respond to external stimuli.
2. Contractility, or the power to move from place to place.

3. Metabolism, or the power to take in food, build it up into its own structure, and thereby grow, as well as eliminating the waste products.

4. Function, or the power to do some sort of work.

5. Reproduction, or the power to make new individuals of its own kind.

These are fundamental in every living body, and in the minute divisions of the body. By the aid of the microscope, it has been found that we are made up of numberless minute cells, each of which possesses the above properties to a greater or less degree. While the cell cannot be considered the *absolute* unit of body structure, it forms a practical basis for study. The investigation of the ultimate subdivisions, the *atom* and the *electron*, bids fair to shed much light upon the physiology of the body.

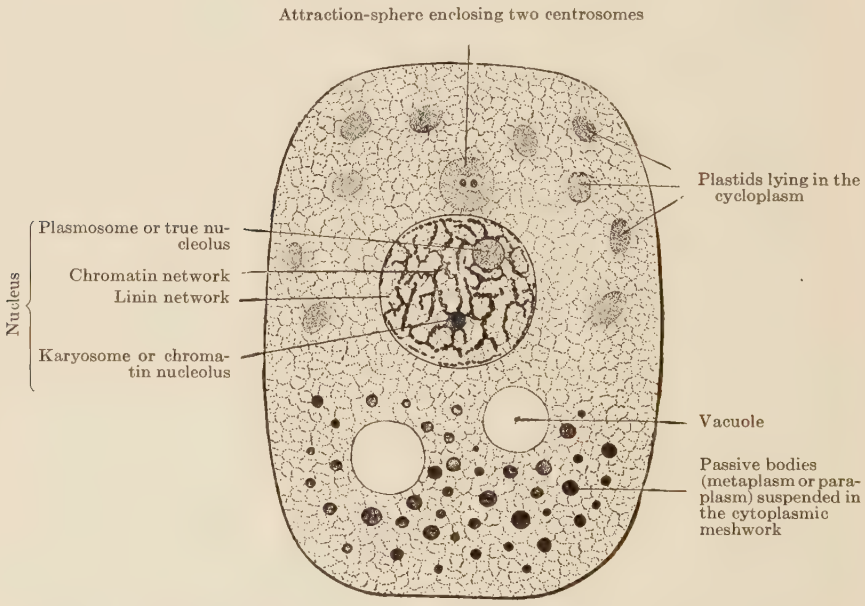


FIG. 3.—Diagram of a cell. Its basis consists of a meshwork containing numerous minute granules (*microsomes*) and traversing a transparent ground-substance. (Wilson.)

THE CELL.

There is now to see just what is meant by a cell, and it may be briefly defined as a *minute mass of protoplasm, with a nucleus.* It may or may not have a cell wall; it may or may not have one or more nucleoli.

The essential parts are the living protoplasm and the nucleus. Protoplasm is the physical basis of life, and is a jelly-like material when examined in life. But, the process of preparing it for microscopical examination kills it so it is difficult to determine its structure. There may be a network of fibers with the fluid portion contained in it, and the nucleus may also have a network. It may be the protoplasm is granular or the granules seen in working cells may be material that has been taken in to be used to make the peculiar secretion of the cell.

The nucleus is essential to a living cell as no reproduction can take place without it.

Chemically speaking the contents of the cell are: Water, salts and organic substances. There are twelve salts in the body, the most plentiful of which is sodium chloride. The organic substances consist of a little phosphorus, some sulphur and proteins, which contain carbon, hydrogen, oxygen and nitrogen. Apparently very little or no carbohydrate or fat is present.

A typical cell is spherical in shape, having a thickened portion, the nucleus, near the center, with the nucleoli showing as darker spots in the nucleus. Near the nucleus or in it is a small spheroidal body called the centrosome. This shows rays proceeding from its center. The centrosome divides in making new cells. Single-celled organisms constitute the lowest forms of life. One of these, the amœba may be studied to show how a single cell will exhibit the properties of living bodies.

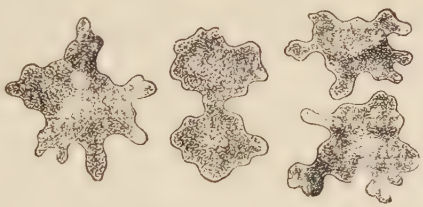


FIG. 4.—Amœboid movements. (Häckel.)

The amœba floats around on the water, as an irregular mass of protoplasm with a nucleus. This mass frequently throws out a long process, and by drawing the rest of itself up to the process changes its location. It has moved, thus proving it possesses the power of *contractility*. In its aimless movements it may come in contact with something that it recognizes as possible food. That response constitutes *irritability*. The organism throws out processes, and gradually surrounds the stray particle, and if it is not suitable for food, it unfolds itself and leaves it. If it is fit for food, it stays until it has taken the particle into itself and grown larger. This shows the property of *metabolism*. When it has become large enough it,

divides into two parts so that it has become two units, that is, it has *reproduced* itself.

Notice the way in which the amœba moves by throwing out a slender process and moving the rest of its fluid mass up to it. Certain cells in the body possess the power of moving in just this way, so they are said to possess the power of "amœboid movement."

Cells are always derived from cells, so the beginning of existence for us must have been as a cell. This cell from which the wonderful human body comes is called the *ovum*.

The *ovum* possesses in some degree all the above properties of life, and after it is fertilized it divides and subdivides until a large number of cells are formed.

Differentiation of Cells.—As the cells increase in number, they separate into layers that have some function especially developed That is, certain cells will be called upon to specialize in contractility, others in irritability, others in secretion, etc.

The process is comparable to a community in which every individual must eat, have shelter and be clothed, and where instead of each one getting his own food, building his own shelter and making his own clothing, certain ones do all the work connected with the food; others do all the building and still others have charge of the clothing. So the various needs of the community are met by the specialization of its members, and the work is done more perfectly. The higher the scale of civilization, the more one sees of such limitation of work to one thing. The higher the grade of living beings the more definitely the cells are specialized and the more impossible it becomes for different kinds of cells to exchange work.

Aggregation of Cells.—In the developing human embryo the first aggregation of cells is into three layers, from which by further and constantly increasing differentiation are finally developed all tissues and organs. Each layer gives rise to its own particular group of tissues.

The Intercellular Substance.—The cell is the actual working unit of the body, and from it is developed a substance that lies outside of it, known as the *intercellular substance*. This varies in amount, sometimes being only enough to unite the cells or it may predominate as in some forms of connective tissue.

The association of a particular type of cell with a particular type of intercellular substance is called a *tissue*. The association of tissues to form a definite structure, to perform some definite function, is known as an *organ*. The association of several organs to perform some definite work, is known as a *system*. For instance, the teeth, stomach, liver, pancreas and intestines are organs that help to form the digestive system.

QUESTIONS.

What is the "anatomical position?"
What constitutes the framework of the body?
Why should the body require "food purveyors?"
What is the relation of the bloodvessels to other parts of the body?
Can you compare the body to a furnace? If so, how?
How do animals differ from plants?
State your understanding of "master organs."
What is the unit of body structure?
What is a "cell?"
Which of the fundamental properties of a living body do cells possess?
Do all cells possess these properties in equal degree?
What is differentiation of cells?
What is a tissue?
What is "amœboid" motion?

CHAPTER II.

THE TISSUES OF THE BODY.

In spite of the great variety of appearance of different parts of the body, they may all be grouped under five heads as belonging to five separate tissues.

Connective tissue is the lowest grade and has much intercellular material and few cells.

Epithelial tissue, the next higher grade has little intercellular substance and many cells.

Blood, the liquid tissue has about an equal division of cells and intercellular substance.

Muscular tissue has little intercellular substance.

Nervous tissue has little intercellular substance, and with muscular tissue is the highest grade tissue in the body. The place of an animal in the scale of existence is determined by the extent and complexity of its nervous system.

The Shape of the Cells.—In the different tissues the shape of the cell is modified by the work performed. In other words, function determines structure, and structure determines function.

The typical cell is a spherical mass. In epithelial tissue this is modified by pressure, into many forms.

In muscular tissue it develops into a long cylindrical cell, more like a section of cord, and suitable for pulling on the bones. In nerve tissue where there must be intimate communication between the various cells, there are many processes or branches.

In the liquid tissue, the solid cells must float in the liquid, so these are either spherical or flattened like disks.

CONNECTIVE TISSUE.

1. *Fibrous.*
   - White fibrous tissue.
   - Yellow-elastic fibrous tissue.
   - Areolar tissue.
   - Adipose tissue.
   - Gelatinous tissue.
   - Adenoid reticular tissue.
   - Neuroglia.
2. *Cartilaginous.*
   - True hyaline cartilage.
   - White fibrocartilage.
   - Yellow fibrocartilage.
3. *Osseous.*
4. *Dentinal.*

The above are the mechanical tissues, or those that support all the other kinds. There is no part of the body into which the connective tissues do not enter, so that if every other tissue were removed the shape of the body would remain exactly as it was before.

White Fibrous Tissue.—The framework of bones serves to support the muscles and enclose delicate organs. The cartilaginous material pieces out some of these uses, besides making the joint surfaces smooth. But the fibrous form of connective tissue, binds muscles to bones by tendons; binds bone to bone, by ligaments; covers and unites muscles, by fascia; forms the framework for all the organs of the body and with a fine mesh sews everything together. If you can get a piece of the small end of a leg of lamb, such as the butcher usually throws away, you may see several of the forms of connective

Fig. 5.—White fibrous tissue. (Gerrish.)

Fig. 6.—Cells of white fibrous tissue, often called connective-tissue cells. (Gerrish.)

tissue. Or the leg of a chicken will do equally well. On the outside of the meaty part (which is muscle), you will notice a white covering which is very tough. It is difficult to detach from the flesh, and if you tease it with a fine needle, it is seen to be made up of fine white threads woven into a sheet.

This is *white fibrous* tissue, very strong, flexible but *not elastic*. It is used where these qualities are required as in tendons, which unite muscle to bone; in ligaments which unite bones to bones at joints; in sheaths that cover muscles as fascia, dipping down between them as intermuscular septa; in the capsules that cover various organs, holding them firmly and in their own place, and forming shelf-like processes which support organs like the liver and intestines. White fibrous tissues forms a part of the covering of bones, as periosteum. By cutting down on the specimen from the butcher you

may see how strong it is and how closely applied. Under the microscope, fibrous tissue is found to consist of very fine fibrils, placed side by side in wavy bundles. A few cells are present, but they do not appear unless the preparation is suitably stained.

Yellow Elastic Tissue.—This is the fibrous tissue that is strong, flexible *and* elastic. It is not fitted to be used in tendons, because it would allow the bones to get out of place during muscular contractions. It is useful in places where it is necessary to have parts return to their original position after being moved away. It is combined with cartilage in the *pinna* or *external ear*, and is plentiful in the ligamentum subflava, connecting the laminæ of the vertebræ.

Fig. 7.—Yellow fibrous tissue. (Queckett.)

Microscopically, yellow elastic tissue consists of rather thick and branching fibers, which curl up at the ends where they are broken.

Areolar Tissue.—If the student will now take the fragment of meat, referred to, and gently pull the fibers apart, it will be seen there are numberless very fine threads holding them together. The threads resemble a spider's web for fineness and delicacy, and on looking carefully, they can be seen everywhere sewing together the larger elements.

Minute spaces between the threads give the name to this tissue though these are not definitely walled. They communicate freely with each other and are bathed in a lymph fluid which increases their flexibility. (When any part of the body is injured, the swelling which follows is usually due to the increase of fluid in the areolar spaces.)

Areolar tissue is found under the skin, connecting it with the underlying tissues; forming a bed for bloodvessels; a bed for nerves; among bundles of muscle tissue; and in the spaces about other kinds of cells, as in glands. It is attached to deeper structures on one side and to the superficial structures on the other. When one of these is moved the areolar tissue allows it to slide for a short distance, by stretching the yellow-elastic fibrous tissue and straightening the wavy bundles of the white fibrous tissue. The skin may be pulled quite a distance and then return to its former position by the yellow elastic fibers drawing the white bundles back to their wavy condition.

The microscopical appearance of areolar tissue, as illustrated, shows a combination of white fibrous bundles and yellow elastic fibers in a network around it.

Adipose Tissue.—This is a modification of areolar tissue, in which the spaces are filled with oil or fat. The connective tissue cells

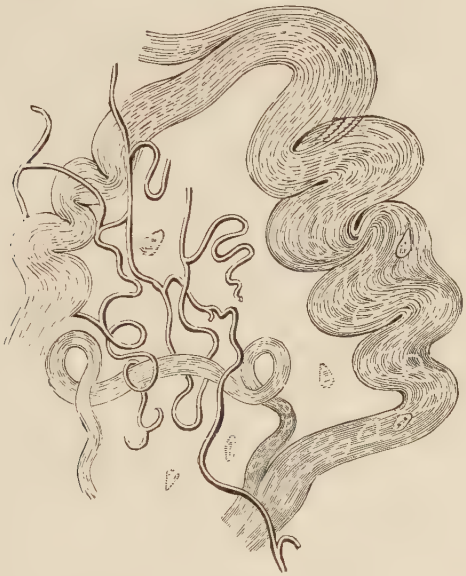


FIG. 8.—Areolar tissue, composed of bundles of white fibrous tissue and branched strands of yellow fibrous tissue loosely intertwined. (Gerrish.)

undergo a degeneration or metamorphosis in which little sacs of oil are formed which are deposited in the areolar spaces. This

FIG. 9.—A portion of areolar tissue inflated and dried, showing areolæ. (Gerrish.)

tissue is practically everywhere, with a few exceptions. It varies in amount, and is sometimes present to a dangerous degree. It

serves as a cushion for organs, as the eyeball and kidney; being a slow conductor of heat, it is a protection against cold; it is a reserve supply of food, and adds grace to the form by rounding out what would otherwise be angles.

Gelatinous Tissue.—This is an immature form of fibrous tissue with a network enclosing a semi-fluid material. The vitreous humor of the eye is an example of this tissue, where it maintains the shape of the eyeball, preventing the wrinkling of the retina (the spread-out optic nerve) as this would blur the sight.

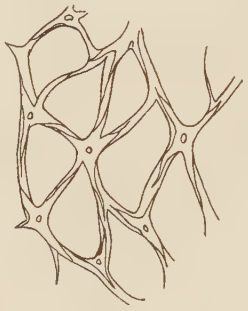


Fig. 10.—Adenoid reticular tissue. (Gerrish.)

Adenoid Reticular Tissue.—This form of fibrous tissue serves as a framework for the irregular masses of leukocytes (white blood corpuscles) which are the active portions of lymphatic nodes, sometimes called lymphatic glands. It is also plentiful in mucous membranes.

Fig. 11.—Neuroglia cells. (Gerrish.)

Neuroglia.—This is a network that supports the nerve substance of the brain and spinal cord. It is not true white fibrous tissue, but is made up of glia cells and their branching processes. These cells are irregular and star shaped with their branching ends frayed out in minute fibrils which go everywhere between the nerve cells and the fibers.

Cartilaginous Tissue (Hyaline Cartilage).—This is composed of a very few cells and much intercellular material. It is bluish-white, dense, smooth and elastic. It covers the joint surfaces of all bones, serving as a buffer and lessening friction; it is placed between bones as a buffer; it connects the ribs with the sternum, adding much elasticity to the thoracic cage; it forms the larynx and most of the nose; and it is the material which keeps the trachea and bronchi from collapsing, so the air may pass through without hindrance. It is covered with a protective and nutritive coat, called *perichondrium.*

White Fibrocartilage.—This is a combination of hyaline cartilage and white fibrous tissue. It is tough, elastic and flexible, and is used to give elasticity to certain structures, as when placed between the bodies of the vertebræ as the intervertebral fibrocartilages.

Yellow Fibrocartilage.—This is a combination of yellow elastic tissue and hyaline cartilage. It is markedly more elastic than hyaline cartilage. It is used to form the epiglottis, etc.

Hyaline cartilage is either temporary or permanent. In fetal life, the long bones are laid down as rods of cartilage, and as the bone salts are deposited in them, the cartilage is replaced by bone. This is the temporary form.

The cartilage on the articular surfaces of bones is always cartilage, and undergoes no change.

Osseous Tissue.—Bone is the form of connective tissue that is of the hardest consistency, exceeded in hardness by two materials only, the dentin and enamel of the teeth.

The hardness of bone is due to the deposition of inorganic substances in the intercellular matrix. These materials are mainly the phosphate and carbonate of lime, though small quantities of other salts are present. These salts are so intimately combined with the osseous structure that though they compose two-thirds of the weight of the bone, they cannot be distinguished as separate by the use of the most powerful microscope.

If the specimen of bone from the butcher is examined, it will be noticed that the bone is pinkish in color, is covered with a thin membrane (the periosteum), and the sawed end shows it to be a hollow cylinder. A pinkish material is in the center (marrow), but if the bone is mature this marrow is yellow. If the specimen is dissected and the joint end exposed, it will be seen to be covered with an opaque, bluish-white material which is cartilage. A thin slice of this may be cut off and examined.

Now, if the enlarged end is sawed through, it apparently consists of a spongy structure (cancellous bone), with the spaces filled with a pinkish (red) marrow. (See Fig. 12.)

Comparing this bone with that of the cylindrical end, it is evident that bone exists in two forms. On the outside of the bone

and forming the hollow shaft the bone is very solid. This is *compact* bone, very strong and heavy. If the entire bony skeleton were of this compact bone, our weight would be so much increased it would be necessary to have much larger and stronger muscles to move the body. To secure the necessary strength without undue weight, the shafts of the long bones are hollow and the expanded ends are made of cancellous or spongy bone which is very light in weight.

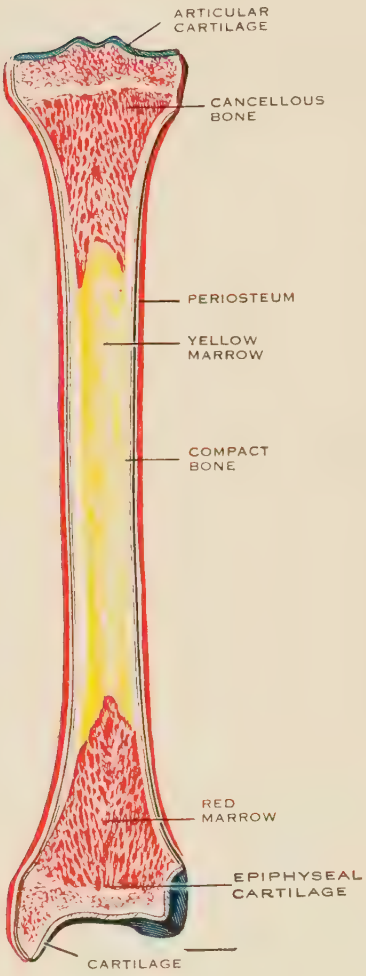


FIG. 12.—Diagram of recent bone.

The specimen from the butcher shows bone as it exists in the body, the so-called "recent state." The dry bones generally used in the study of anatomy, have had all the soft tissues removed, making them much pleasanter to handle.

Bone consists of animal and mineral matter, 36 per cent of the former and 64 per cent of the latter. When the animal matter has been burned out, the bone remains of the same shape, but is very brittle, crumbling easily. If the mineral matter is removed by soaking in dilute acid, the shape is not changed, but it has no rigidity. It may be bent and twisted in any direction. The appearance under the microscope remains the same in both cases.

It is in the minute structure that the essential life of bone is carried on. Like the other forms of connective tissue it is made of cells and intercellular substance, of which the latter predominates. The working part or cells are ovoid in shape, nucleated and with numerous small processes. These cells lie in spaces called *lacunæ* (little lakes). From the lacunæ pass minute canals (*canaliculi*) which join with those from other lacunæ, so there is a complete system of little canals through which passes the nutritive materials.

The intercellular substance is in fibrous layers in which the mineral salts are deposited. These layers are called *lamellæ*. By reference to Fig. 13 the plan of the structure of bone may be seen in detail. The Haversian systems are seen in Fig. 14 under slight

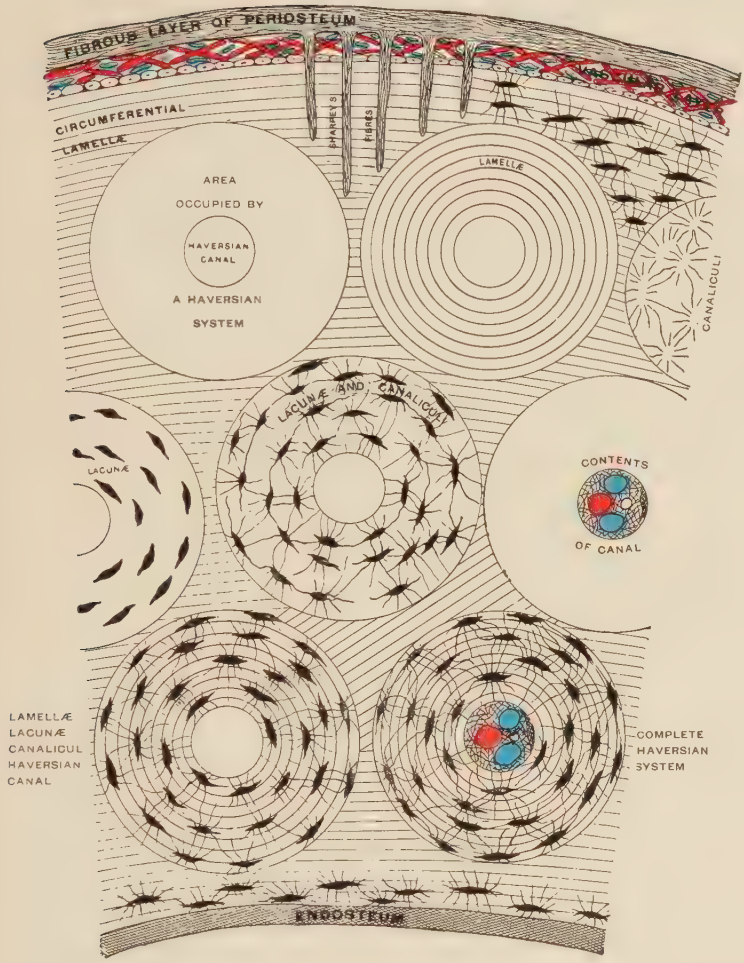


FIG. 13.—Diagram of the structure of osseous tissue. A small part of a transverse section of the shaft of a long bone is shown. At the uppermost part is the periosteum covering the outside of the bone; at the lowermost part is the endosteum lining the marrow cavity. Between these is the compact tissue, consisting largely of a series of Haversian systems, each being circular in outline and perforated by a central canal. In the first one is shown only the area occupied by a system; in the second is seen the concentric arrangement of the lamellæ; and in the others, respectively, canaliculi; lacunæ; lacunæ and canaliculi; the contents of the canal, artery, vein, lymphatic and areolar tissue; lamellæ, lacunæ and canaliculi; and, finally, all of the structures composing a complete system. Between the systems are circumferential and intermediate lamellæ, only a few of which are represented as lodging lacunæ, though it is to be understood that lacunæ are in all parts. The periosteum is seen to be made up of a fibrous layer and a vascular layer, and to have upon its attached surface a stratum of cells. From the fibrous layer project inward the rivet-like fibers of Sharpey. (Gerrish.)

enlargement. The small dots seen on the sawed end of bone are the Haversian systems with the canals in the middle.

In the shaft of a bone, one or more rather large holes are seen through which pass the nutrient artery. Other openings (*foramina*) which serve the same purpose are seen near the expanded ends.

FIG. 14.—*A*, transverse section of a long bone, natural size; *B*, the dark part of *A*, magnified 20 diameters. • Haversian systems of different sizes are seen, with canals, lamellæ and lacunæ. The enlargement is not sufficient to show canaliculi At *b* is a portion of the cancellated tissue. (Peaslee.)

The *periosteum* is made up of two layers, the outer fibrous, and the inner consisting of a network of capillaries and osteogenetic cells. These latter are epithelial cells that secrete from the blood the materials that make bone. Growth and repair of bone take place by means of the periosteum, If any considerable portion of this is destroyed, the unprotected portion of bone dies. From the fibrous layer of the periosteum go prolongations into the bone that are called "Sharpey's fibers." They attach the periosteum firmly to the bone.

Dentinal Tissue.—This makes up the bulk of the tooth substance and is covered by a still harder material, the *enamel*. It is similar to bone, but instead of having the Haversian systems, there are radiating tubules that carry the nutritive materials.

EPITHELIAL TISSUE.

If we look at our own skin, we see a good example of this tissue, for while the skin contains other tissues, it is essentially an epithelium. The lining of the nose, mouth, eyelids, ears and the covering of the tongue are likewise epithelium. We find that every free surface of the body, including the internal organs is covered with this tissue. Every cavity is lined with it. If the skin is broken or a part of it is brushed off as in a burn or blister, we realize what a protection this epithelial tissue is to the sensitive underlying parts besides preventing the escape of the fluids within.

If we touch the lining of the mouth we realize how this tissue imparts smoothness to surfaces. This is true also of the lining of bloodvessels and cavities in the trunk and cranium.

In the mouth is a fluid named *saliva* that is always present, no matter how much may be used in mostening food. It is made by the epithelial cells in the salivary glands. These are like little factories, taking the materials brought by the blood and manufacturing something different. This making of *secretions* is exclusively the property of the epithelial cell, providing different secretions for the various uses.

The gastric juice, the bile, the fluid in the brain and spinal canal, the wax in the ear, etc., all, are made by the epithelial cells.

When food has been transformed into such a state that it can become a part of the blood, the epithelial tissue attends to transferring it from the alimentary tract to the bloodvessels. Certain cells have waving processes (cilia) that keep the fluid with which they are in contact moving along, carrying it toward the exterior of the body. It is in this way that mucus in the bronchial tubes is carried to the place where it can be coughed up and expectorated.

And, lastly, by this tissue certain sensory impressions, as those brought to the ear, are helped to be appreciated by the brain.

All this work mentioned above is done by cells of microscopical size and of varying shapes. The typical epithelial cell is spherical with a rather large nucleus, resting on a delicate connective tissue, *basement membrane*. The cells are held together by a very small amount of intercellular substance called "cement" substance. There are no bloodvessels in the tissue, but it is supplied by loops of capillaries coming up to the basement membrane. It is scantily supplied with nerves.

This tissue after being destroyed is quickly replaced. The skin, as an instance, heals in a short time after being broken. Spherical cells are not usually seen as they would require too much room, so they are crowded together, with the shape being changed according to the direction of the pressure. If the pressure is sideways, the cells become tall and like columns, forming columnar or cylindrical

cells. If the pressure is from above, they are flattened, as in pavement or squamous epithelium. If it comes from all sides the cells become polyhedral. A few modifications of these forms should be considered.

Ciliated columnar cells have delicate processes projecting from their free surfaces, which move constantly, waving back and forth with a stronger motion in the direction toward the surface of the body. They keep fluids moving and are numerous in the respiratory tract, and in a few other locations.

Pigmented cells are irregular in shape and contain dark particles called *pigment.* They give the dark color to the skin and some other structures. In the skin this pigmentation protects the sensory nerves against the light.

FIG. 15.—Two conoidal epithelial cells, their free ends furnished with cilia. (Gerrish.)

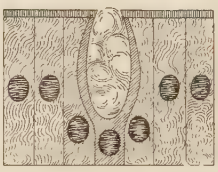


FIG. 16.—Goblet-cell, surrounded by cylindrical cells. (Gerrish.)

Goblet or *chalice cells* are specialized columnar cells found in mucous membranes. In these cells the nucleus is usually about the middle, but when activity begins it sinks to the bottom, the cells fill with granular material which swells, making them larger and crowding those nearby. Finally, the pressure within becomes so great, the cells break and their contents comes out on the surface as *mucus.*

Glandular epithelium is composed of cells of varying shapes according to the shape of the cavities to which they adapt themselves (Fig. 17).

Membranes.—Epithelium may be in a single layer or in several layers (*stratified*). A number of cells arranged in one or more layers is called a *membrane.* The skin has a number of layers, one above another, the structure being called a *cutaneous membrane.*

When an epithelium imparts smoothness to a surface, or covers it and forms a secretion on such surfaces as communicate with the outside air, the structure is called a *mucous membrane.* Under similar conditions if the surface does not communicate with the outer air, the structure is a *serous membrane.* The lining of the

mouth and of the stomach are examples of mucous membranes, while the covering of the lungs and heart form serous membranes.

The epithelium that lines the capsular ligament of joints does not communicate with the air, so it is similar to the serous membrane, but it is given a special name, *synovial membrane.* It secretes a fluid called *synovia* for lubricating the joints.

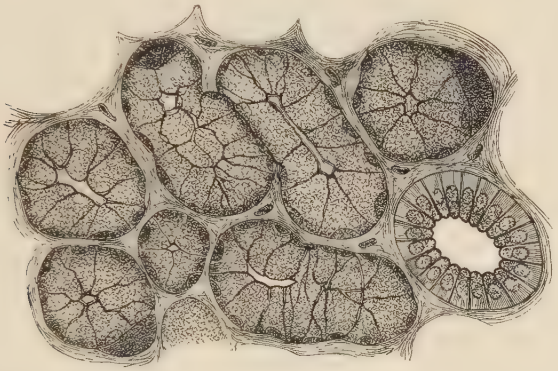


FIG. 17.—Glandular epithelium as seen in a salivary gland. At the lower right-hand corner is a duct lined with conoidal epithelial cells. (Kölliker.)

There are some other situations in which *synovia* is found, besides the joint cavities. The tendons of muscles may rest in grooves on the bones, so these grooves are smooth-lined by synovial membrane and lubricated by the synovial fluid. These are called *vaginal synovial membranes* or *synovial sheaths. Bursal synovial membranes* line bursæ. These are little sacs of fibrous tissue, placed between parts that move on each other as a muscle over a bone, one muscle over another or the skin over a bone. Their function is to impart smoothness to the surfaces and provide lubrication to prevent friction.

Glands.—Glands are masses of tissue of various sizes and shapes whose function is the manufacture of special fluids from the blood. If the material manufactured is to be used again in the body, it is usual to call it a *secretion,* but if it is to be thrown off, it is called an *excretion.* The use of these terms is arbitrary and the best authorities tend to call both by the name *secretion.*

The elements concerned in the work of the glands are:

1. Epithelial cells, which from materials brought by the lymph and built into its substance, produce some specific secretion.

2. The lymph which contains the materials for the nutrition of the cell and its product.

3. The arterial capillaries that permit the exudation of lymph from the blood.

4. Secretory autonomic nerves that determine the production or non-production of the specific substance.

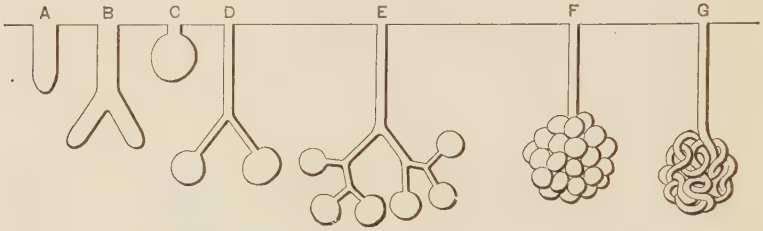


FIG. 18.—Diagram showing development of glands: *A*, a mere dimple in the surface; *B*, enlargement by division; *C*, enlargement by dilatation; *D*, a combination of *B* and *C*; *E*, a racemose gland; *F*, development of method of *E*; *G*, a single tube intricately coiled. (Gerrish.)

5. The vasomotor nerves which permit the dilatation of the blood-vessels so increasing the supply of lymph or constrict them, thus lessening the supply, after activity.

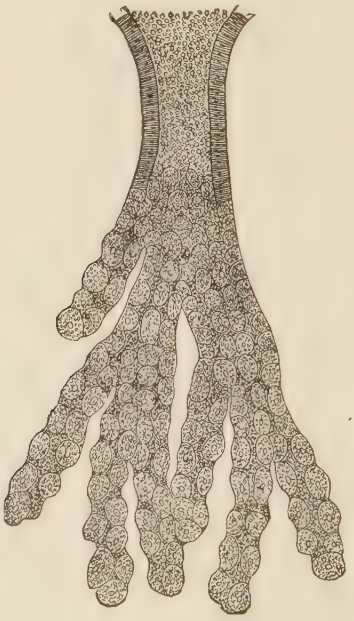


FIG. 19.—Compound tubular gland. The upper part is the duct; the lower is the secreting portion. (Kölliker.)

This secretion may be carried from the gland by a duct to some organ. To this the name of *external secretion* is applied. There may be no duct, and the secretion may be returned directly to the

blood, as an *internal secretion*. Such glands are called *ductless glands*.

FIG. 20.—Compound racemose gland. The resemblance to a bunch of fruit is very marked. (Milne-Edwards.)

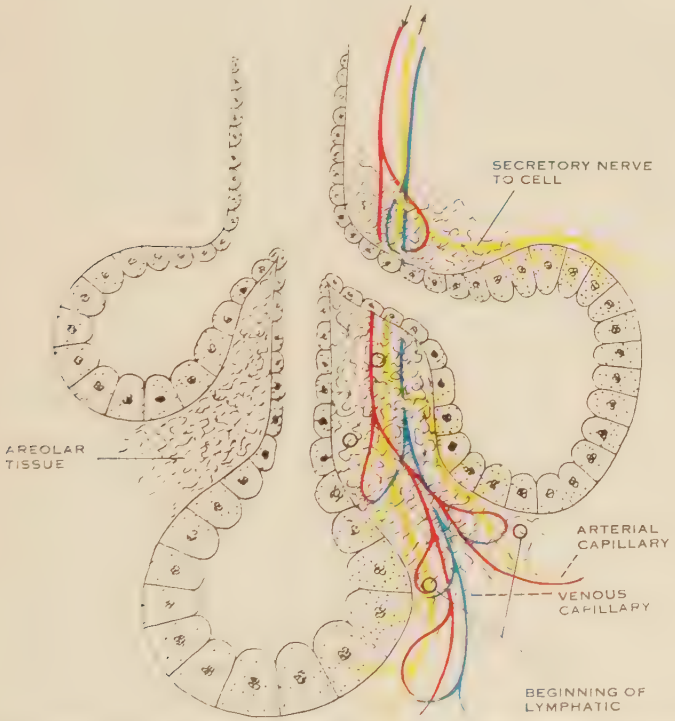


FIG. 21.—Diagram showing gland cells during rest. Also showing blood and nerve supply.

The simplest form of gland may be said to be represented by the goblet cell, which secretes mucus. It is on the surface, but all the glandular work of the body cannot be carried on at the surface,

as there is too much chance of interference and injury. The next most simple arrangement is a dipping down of the surface, so a group of epithelial cells may line a shallow tube. This would be called a "follicular" gland. The secretion is thrown out on the

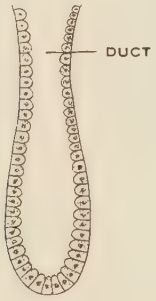


FIG. 22.—Simple tubular gland.

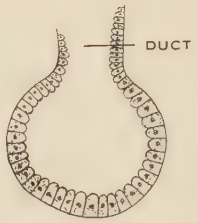


FIG. 23.—Simple racemose gland.

surface without any special duct. But, if the upper part becomes narrowed, and the cells covering it give up their secreting function, becoming simply a lining, a duct has been formed through which the secretion passes. The gland is tubular, and may be elaborated to any degree by branching. This is one type (Fig. 22).

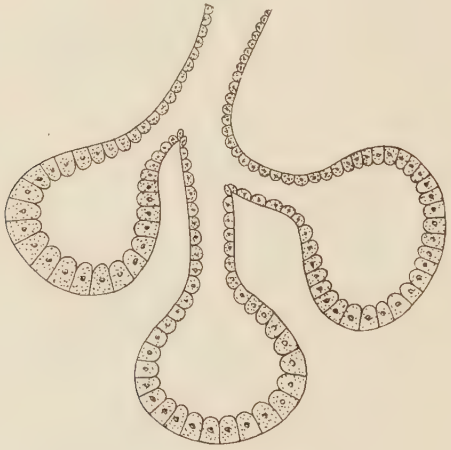


FIG. 24.—Compound racemose gland.

If the dipping down becomes bulbous or globular by dilating it is called "racemose," and this is a second type. It may increase by division and subdivision and combination until it becomes a compound gland (Fig. 24).

A fibrous network supports and gives shape to the divisions of

compound tubular or racemose glands. In the network run the bloodvessels that supply the cells with nutriment and working material, and the beginnings of the drainage tubes that carry off the waste or excess of material. The nerves that control the work of secretion are also found in this network. (Fig. 21.)

It should be remembered that the epithelial cells are microscopical in size, a small fraction of a millimeter in diameter and all the wonderful work that takes place in them is done by the aid of other microscopical structures.

Glands have working periods and resting periods. During rest, there is an accumulation of granular material in the cells. After a gland has been working for a time, the granular material has decreased or disappeared, apparently undergoing chemical changes in forming the secretion peculiar to that gland. An increased amount of blood is carried to a working gland, and, by the same control that increased it, the amount is lessened when the gland is not working.

There are two ways for the amount of activity and the quality of the secretion to vary. If the blood supply increases without additional stimulation of the cell by the secretory nerves, the secretion is more profuse but thinner. If the secretory stimulus is increased, with correspondingly increased blood supply, the secretion is increased in amount without change in its character.

MUSCLE TISSUE.

This is the tissue in which contractility is especially developed. It is found in three forms:

1. *Striated,* or cross-striped.
2. *Smooth,* or plain or non-striated.
3. *Cardiac.*

Striated Muscle.—Striated muscle is that form of the tissue which is attached to the bony skeleton, is under the control of the will and has to do with such manifestations as are peculiar to animals, *i. e.,* as motion.

It makes a large portion of the bulk of the body and is identical with what is known in the lower animals as lean meat. The specimen from the butcher, before referred to, should be examined to see its physical properties.

In color it varies from a deep red to a pale pink, according to the amount of blood contained and the size of the fibers. It is somewhat elastic, is easily torn and is attached to the bones by means of tendons or directly through the periosteum. A coat of fibrous tissue covers every appreciable amount of it, and even its unit of structure, the fiber, is covered with fibrous material. The tendon

is made up from the aggregation of the coverings extended beyond the fiber.

There are various ways in which the fibers are placed in regard to the tendon. Sometimes the bundles of fibers are parallel and spindle-shaped, with the tendons at each end: the fusiform arrangement. Or, the tendon may be at one side with the fibers placed at an oblique angle with it. This is the "penniform" arrangement. There may be fibers on both sides of the tendon, the "bipenniform" arrangement. These arrangements vary according to the work to be done.

The tendon, instead of being cord-like may form a sheet that covers much of the muscle, as an "aponeurosis."

Or, there may be several rows of muscle fibers with lines of tendon crossing them, forming a "tendinous inscription."

The Muscle Fiber.—The fiber is the unit of muscle tissue. It is cylindrical in shape, with rounded ends. On the outside is a delicate fibrous sheath, the *sarcolemma.*

Fig. 25.—Part of a fiber of cross-striped muscular tissue, showing the alternating bands. (Gerrish.)

If the fiber is placed under a microscope of moderate power, it appears to have cross-way stripes or striations. These give the name to this class of muscle tissue. Besides the cross stripes there are very delicate lines longitudinally. Under a high-power microscope, the fiber appears to be made up of a number of parallel fibrils, having long spindle-shaped processes alternating with round

bead-like ones, with constrictions between them. These fibrils are the contractile portions of the fiber. When they contract, the spindles and beads shorten longitudinally and broaden transversely. Between the fibrils is a liquid material, the *sarcoplasm*, which is pushed aside by the change in the contractile elements, so the muscle fiber shortens and broadens in contraction.

An essential part of the muscle cell or fiber is the motor nerve ending. Every cell has its motor nerve by which it is stimulated to contract. So intimate is this arrangement that it is fair to speak of a muscle fiber as a muscle and nerve combined. (Foster.)

FIG. 26.—Diagram showing the minute structure of cross-striped muscular tissue. (Gerrish)

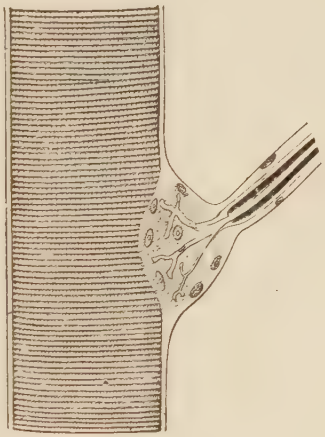


FIG. 27.—Motorial end-plate, the termination of a nerve in a fiber of cross-striped muscle. (Testut.)

The muscle contracts after it is stimulated by the nerve, and then it rests until another stimulation occurs. Each contraction may be compared to an explosion which follows the stimulus, and the more frequent the stimuli, the more frequent the contractions.

If a proper apparatus is arranged, so the contractions may be shown on a paper placed on a revolving drum, some such figure as in Fig. 28 would result. It would show that the muscle does not contract the instant the stimulus is applied, but there is a time of preparation, after which the contraction occurs reaching a maximum intensity and then declining from this maximum to the end of the contraction. This time of preparation is called the "latent" period. In Fig. 28 the time at which the stimulus is applied is indicated by "S."

In a fiber are many fibrils bundled together, the fibers being grouped in a bundle, and this bundle with other bundles, until the bundles of bundles become a real muscle as seen in the body by the naked eye. Each successive group has its own fibrous investment.

Fig. 28.—Curve of simple muscular contraction.

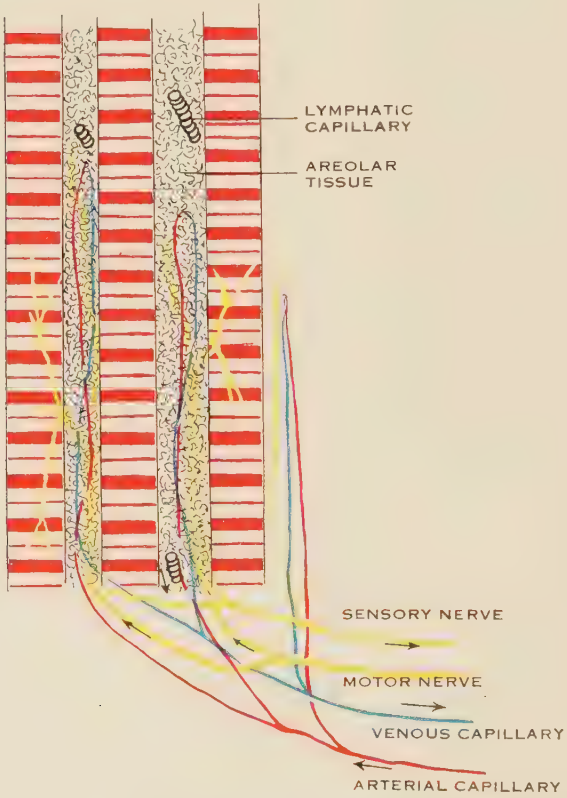


Fig. 29.—Diagram of muscle tissue with arrangement of bloodvessels and nerves.

Fibers vary in length from $\frac{1}{5}$ inch to 2 inches. In width they vary from $\frac{1}{2500}$ of an inch to $\frac{1}{250}$ of an inch. If the muscle is more than 2 inches long, the fibers are joined end-to-end to make up the necessary length.

Between the fibers is areolar tissue in which run the bloodvessels, including the lymphatics and the nerves.

Plain or Non-striated Muscle Tissue.—This is the form of muscle which is not under the control of the will, but is stimulated by the

FIG. 30.—Cells of plain muscular tissue. (Gerrish.)

FIG. 31.—Cell of cardiac muscular tissue. (Testut.)

sympathetic nervous system, in its work of contraction in the walls of hollow viscera and bloodvessels. It aids in the performance of those functions that are called "vegetative."

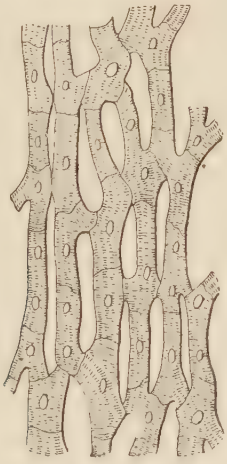


FIG. 32.—Cardiac muscular tissue, the cells united in a network. (Testut.)

These fibers are not arranged in bundles but in sheets. The fibers run around the vessel or lengthways of it, and in the hollow viscera they may go in all directions.

The microscopical unit is the cell or fiber, which is fusiform in shape. About the middle of it is some granular material and quite a large nucleus. The size varies from $\frac{1}{500}$ to $\frac{1}{10}$ of an inch in length, with the width a fraction of these.

A delicate sheath covers each cell, with areolar tissue surrounding it. The color is pale, and their blood supply less profuse than is that of the voluntary muscles.

The contraction of this tissue occurs in a long-continued rhythmic wave, which can be well seen in a freshly killed animal when a stimulus (blow) is given to the coil of intestines. This rhythmic wave in the digestive organs is called *peristalsis.*

Cardiac Muscle Tissue.—This is a form found only in the heart. In appearance it has some of the characteristics of both the striated and non-striated muscle.

It presents irregular cross-striations, but the cells are short and branched, with large nuclei. It is not under the control of the will, though it is affected much by the emotions. The cells are arranged in a network, with many open spaces, by being joined end-to-end. The blood supply is very ample. The contractions are rhythmic, with waves passing in a circular fashion around the cavities of the heart. These contractions are followed by periods of rest.

NERVOUS TISSUE.

This is the highest grade tissue in the body, the master tissue, and the most difficult to replace if destroyed or injured. It is found all over the body, with aggregations in the brain, the spinal cord and in the trunk in front of the spinal column. It is usually divided into gray and white nervous tissue. The gray matter is pinkish-gray in color, found on the outer surface of the brain, the center of the spinal cord, and in the masses in the trunk. It is the active part of the tissue, receiving impressions, sending orders, coördinating, considering, remembering and originating impulses. It consists of cells. The white matter consists of fibers of gray matter covered by a coating which protects it. These fibers simply carry messages to and from the centers, but do not originate any.

The Neurons.—The unit of nerve tissue is the *neuron.* This is a granular, pigmented, branched and nucleated cell that always has at least one long process called the *axone* or axis-cylinder process. This axone is prolonged as a fiber, going to some part of the periphery. The branching processes are called *poles.* These divide and subdivide into protoplasmic processes called *dendrites.* The axone may remain without coating as a gray nerve fiber, or it may become invested with the white coating and become a white nerve fiber. This covering is soft and oily, known as the medullary sheath

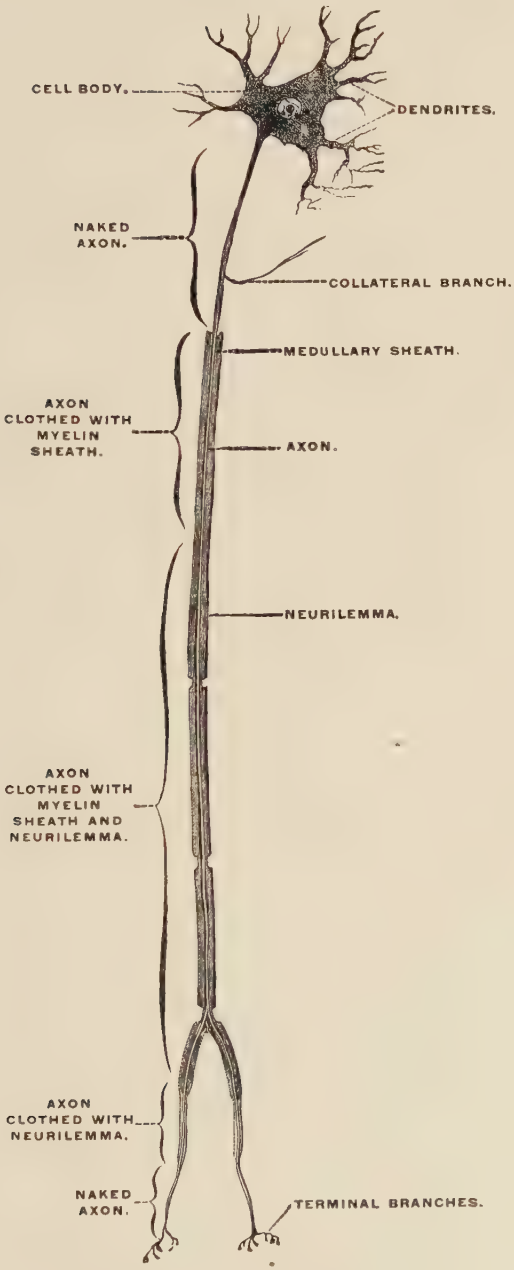


FIG. 33.—A neuron. (Stöhr.)

or "white substance of Schwann," and it is surrounded by a fibrous sheath, the *neurilemma.*

The medullary sheath covers the fiber except at intervals where only the neurilemma invests it. These intervals are called the "nodes of Ranvier." At its termination, the axone divides into a number of branches from which the coating is absent.

The nutrition of the nerve fiber is through its cell. When the fibers are separated from their cells, degeneration, either upward or downward ensues. A similar degeneration occurs in muscles when they are separated from their nerve supply. The "reaction of degeneration" is determined by the varying response to the stimulation of different electrical currents.

Nerves as seen in the body look like white cords, of varying size. They consist of a bundle of fibers, held together by areolar tissue, in the meshes of which run the bloodvessels and lesser nerves which nourish them.

Nerve fibers carry messages in two directions, either from or to the center. Those that carry from the center are called "efferent" and grow from the center outward, as the motor nerves.

Those which carry to the center (afferent nerves) grow inward from the nerve cells in organs of special sense or the tactile corpuscles (touch), etc., and their fibers branch within the nerve centers and communicate with the cells. Afferent or sensory nerves pass between the muscle cells to sensory centers.

THE LIQUID TISSUE.

This is known as the *blood,* a red, opaque fluid, having a peculiar stale odor, a salty taste, somewhat viscid and of an average specific gravity of 1055. This varies according to the amount of water ingested.

The temperature of the blood averages 98.6° F., or 37° C., with a higher temperature in the deeper vessels, and even 107° F. in the vessels of the liver.

The weight is estimated as one-eleventh that of the body.

The reaction of the blood is slightly alkaline. This is essential to the life of the cells, as they cannot function in acid surroundings. Faulty action of the liver and kidneys, as well as errors in diet, may cause an acid condition of the blood.

About one-half the bulk of the blood is a fluid, the *plasma,* in which float innumerable minute solid bodies, called cells or corpuscles—red or white.

The Plasma.—The plasma is clear and transparent, of a very light yellow tinge. It is practically identical with *lymph.*

While the blood is in a system of closed tubes its liquid part is plasma. When this has oozed through the walls of the capillaries

into the spaces surrounding them, the fluid is called *lymph*. (The terms "perivascular," "intercellular" and "lymph spaces" refer to the same spaces, but as they relate respectively to the capillaries, the cells and the lymphatic vessels.) A specimen of the lymph may be seen in the watery fluid that exudes when the skin over a blister is broken.

If a quantity of blood is drawn from the body, and allowed to stand in a glass tube, there is, presently, a division into a solid dark-red mass at the bottom and a clear, light-yellow fluid above. This fluid is *serum*, and the use of the term always means it is outside the bloodvessels. It is distinguished from plasma by the lack of fibrinogen, an antecedent of fibrin. The solid mass is *clot* or *coagulum*, made up of corpuscles or cells caught in a network of fibrin. Plasma itself, when removed from the bloodvessels, will coagulate, forming a soft clot of fibrin and the clear serum. Apparently, the corpuscles are not needed to induce clotting, but some elements in the plasma are always concerned (page 56).

Plasma has a specific gravity of 1026 to 1029. It is 90 per cent water in which are dissolved various proteins, sugar, fat, amino-acids, inorganic salts, waste materials, including urea, new food materials, etc., in addition to oxygen, nitrogen and carbon dioxide. The 10 per cent solids consist of:

Proteins	8.200
Amino-acids	0.005
Fats	0.250
Sugar	0.100
Broken-down material	0.600
Inorganic salts of sodium Potassium, calcium and magnesium	0.850

The percentage of amino-acids in the plasma is much increased soon after a meal, especially if much protein food was taken. Apparently, part of these amino-acids are built up into the tissue cell during the intervals between meals. A part may be transformed in the liver into urea.

Soon after a meal the percentage of sugar and fat also are increased.

The products of katabolic activity that enter the plasma includes urea, uric acid, creatinin, ammonia and other nitrogenous compounds. These materials are being produced and removed during life, so the percentage remains fairly constant in health.

Plasma may be considered as representing the intercellular material between the cells or corpuscles. There is about an even division as to bulk.

Corpuscles, or Cells.—These are in three classes:

1. *Red corpuscles* (*erythrocytes*), numbering 4,500,000 to 5,000,000 per cubic millimeter.

2. *White corpuscles* (*leukocytes* or *lymphocytes*), from 7000 to 10,000 per cubic millimeter.

3. *Blood platelets* (*thrombocytes*), about 200,000 per cubic millimeters.

A fourth element is the *blood dust* or hematokonia, of which very little is known. It appears as minute refractive granules, and may be the fragments of broken-down red corpuscles.

Red corpuscles are minute bodies visible under a low-power microscope. Singly, they have a pale yellow color, but in mass are red.

Examination on a slide shows them as biconcave, circular disks, which have a way of rolling up like a pile of coins. When fresh blood, mixed with a normal saline solution (0.06 per cent) is examined, or the circulating blood is studied, the corpuscles are seen to be bell-shaped. Their greatest diameter is 0.007 mm., or they are of a size to go single file through the smallest capillaries.

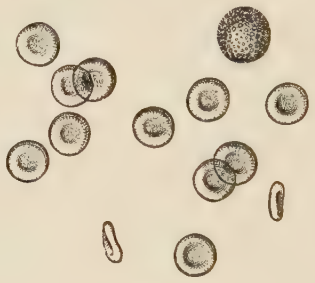


FIG. 34.—Blood corpuscles. One colorless corpuscle is seen at the top; the others are colored. (Dalton.)

The red cells have no nucleus. It is claimed that there is a surrounding colorless membrane, in which is a semi-fluid mass, consisting of protein, lecithin, cholesterin, hemoglobin and various inorganic salts. The *hemoglobin* represents 94 per cent of the solid matter, while there is 65 per cent water.

Hemoglobin is very complex, consisting of carbon, oxygen, hydrogen, nitrogen, sulphur and iron. Iron equals 0.33⅓ to 0.5 per cent of the whole. Estimates place the total amount of iron in the body as 2.9 gm. While this amount is very little, its presence in hemoglobin enables the red corpuscles to combine with and carry oxygen from the air in the lungs to the ultimate tissue cells. After this there is a release of alkaline material from the hemoglobin, which combines with the CO_2 waste from the tissues, producing bicarbonates of soda and potash, in which form the waste is carried to the lungs.

Red corpuscles are daily destroyed in large numbers and new ones made. It is supposed the destruction takes place mainly in the spleen and the liver. New corpuscles seem to be made in the red marrow of the bones. Large nucleated cells called *erythroblasts*

develop from marrow cells. They divide and multiply, becoming known as *normoblasts*. At first they have nuclei, but these lessen in size and are finally thrown off. The rest of the body goes out as a red corpuscle.

This theory of the formation of erythrocytes is strengthened by the fact that after a severe hemorrhage the process of new cell production is so rapid, some of the erythroblasts and normoblasts get out into the blood stream before they have thrown off their nuclei.

In various animals the red cells differ in size and shape, according to the need for respiration, but microscopically those of mammals are virtually the same as those of man.

White Corpuscles.—The white cells are colorless, but in the mass are white. They are spherical, larger than the red cells, contain a variable number of nuclei, and by virtue of their power of "amœboid movement," can get out of the bloodvessels into the perivascular spaces. Their name of "wandering cell" refers to this peculiarity.

By their reaction to staining agents, white cells are divided into two groups:

The first group, comprising 25 to 30 per cent of the whole number, are *lymphocytes, small* or *large*. These develop in the lymph glands, solitary follicles, etc. They are washed out of the glands by the lymph, and so enter the blood stream. They seem to be mainly useful in limiting the spread of infections by blocking the lymph spaces, or "walling off" the infected areas.

The second group developing from the *myelocytes* in the red marrow, comprise "polymorphonuclear" leukocytes (60 to 70 per cent of all white cells), the *eosinophiles* and the *basophile* cells. This group is supposed to remove broken-down tissue and invading bacteria. By their amœboid movement they go out into the tissue spaces, surround and take in these substances—digesting them. This process is called "phagocytosis," and the cells are called *phagocytes*. This work is helped by the development in the tissues of a material which gets into the plasma. This is "opsonin," and its quantity probably measures the resistance of the organism to infection. Inflammation with pus formation (another protective agency) increases the number of leukocytes. The débris of the broken-down tissue, plus the dead phagocytes equals *pus*.

Leukocytes may also absorb fat from lymphoid tissues in the intestine. They presently die and add protein to the plasma, which *may* help in the coagulation of the blood.

Platelets.—These are very minute corpuscles without nuclei, but with a central granular and clear bordering structure. They are about 2 microns in diameter, and seem to be disk-shaped—possibly biconcave.

With fibrin they form most of the thrombi that develop in

diseased bloodvessels. Their function is unknown, but it may be to help in the coagulation of the blood. When their number in the blood is much decreased, coagulation occurs very slowly.

In the plasma the nutritive materials from the foods are present, while the red cells carry the oxygen.

Blood containing all these various elements is a carrier, taking:

The products of digestion to the tissues.

The waste products from the tissues.

The oxygen taken in by the lungs to the tissues.

The carbon dioxide waste from the tissues to the lungs.

The internal secretions from the ductless glands to the tissues; *and* it is also instrumental in regulating the heat of the body.

Functions of the Liquid Tissue as Related to Cells.—The lymph surrounds the various tissue cells, constantly bathing them. According to the hydraulic pressure within the cells or in the lymph, the cells take up their needed elements from the lymph or exude the waste material. It is supposed that the metabolism of a part of the protein and of all the carbohydrate and fat occurs in the lymph spaces. Only a part of the protein is built up into the cell structure.

Nutritive and waste materials are both present all the time. The means by which the lymph enters and leaves the lymph spaces will be discussed in the Chapter on the Circulatory System.

QUESTIONS.

Name the commonest forms of fibrous tissue.

What are the characteristics of white fibrous tissue that make it useful as ligaments and tendons?

Name the uses of cartilage. Where is it found as a temporary structure?

Describe the structure of "recent bone," and tell the uses of its parts.

State the uses of epithelial tissue.

What are glands?

Why is striated muscle tissue connected with bones instead of being in the walls of the stomach?

Describe a neuron.

Describe blood.

What is lymph?

Examine the leg of a chicken and identify all the tissues.

CHAPTER III.

THE OSSEOUS SYSTEM.

Structure of Typical Bone.—Bones form the framework or skeleton of the body, to which the muscles which move different parts are attached; they support and protect soft parts which are concerned in the more vital functions, as the brain, thoracic, abdominal and pelvic viscera. Usually the bones that form cavities are broad and flat, while those that have to do with the leverage of muscles are elongated. Structure varies according to use, so there are three different classes of bones, flat, irregular and long.

Classes of Bones.—Flat bones have outer layers or "tables" of compact bone, with an inner filling of spongy bone. The irregular bones are similarly covered with compact bone with spongy bone within, and are of such varied and irregular shapes they cannot be classified as either flat or long.

Long bones, regardless of absolute length, have hollow cylindrical shafts of compact bone, with expanded ends of cancellous bone, covered with a thin shell of compact bone. The expanded ends provide increased surfaces for joints, while the hollow shafts ensure sufficient strength with little weight and provide space for certain nutritive elements as the marrow and bloodvessels. In the embryo, bones are preformed in either cartilage covered with membrane or in membrane alone. As development proceeds, bone-salts are laid down under the membrane in spots called "centers of ossification." In long bones, these centers are in the shaft and extremities. As the process proceeds the main shaft, called the diaphysis becomes entirely ossified and the extremities, or epiphyses, likewise, but until the time arrives when growth is completed, a layer of cartilage, the epiphyseal cartilage, remains between them. When this is finally ossified, the bone is said to be "mature." All bones do not reach maturity at the same age. Usually between the ages sixteen and twenty-two years the various bones attain their full growth, though occasionally the process is not completed until the twenty-fifth year (Fig. 12).

Long bones increase in length by these additions at the ends, but the increase in girth or diameter occurs by the laying down of bone-salts under the periosteum.

Flat bones increase in size by additions at their edges, as in the bones of the skull.

The surface of bones varies much according to the age and the muscular development of the individual. As the muscular use

increases the bones show more distinct roughness. (In selecting bones for study pick out those that show the various markings most distinctly.)

Markings on Bones.—The markings on bones may be either elevations or depressions. The elevations include, *tubercle,* a blunt prominence smaller than a *tuberosity; spine,* which is a sharp prominence; *process* which may be an outgrowth of any shape or size; *ridge, crest* or *line* when narrow; *condyle* if broad and articular, and *head* if supported on a neck. Depressions of bone include *fossa* and *cavity,* which are more or less shallow; *foramen,* a hole; *fissure,* a narrow slit; *canal,* a long tube-like passage way.

Muscular Attachments on Bones.—The muscular attachments to bone are denominated origin and insertion, considering origin the fixed point and insertion the movable point, but as these are frequently reversed in action, it is more satisfactory to consider origin as referring to the attachment nearer the center line of the body or the upper part of an extremity, and insertion that more distant from these points. No description fits all specimens as no two bones are exactly alike either in size, shape or markings.

THE BONES OF THE SKELETON.

The skeleton in the adult consists of 206 bones (including the small bones of the ear) grouped as follows:

The bones of the head (22).

8 cranial bones	1 frontal
	2 parietal
	2 temporal
	1 occipital
	1 ethmoid
	1 sphenoid
14 facial bones	2 malar
	2 lachrymal
	2 nasal
	2 superior maxillary
	2 palate
	2 turbinate
	1 inferior maxillary
	1 vomer

The bones of the trunk (52).

24 vertebræ.
1 sacrum.
1 coccyx (sometimes four or five).
24 ribs.
1 sternum.
1 hyoid.

The bones of the upper extremity (64) or 32 on each side.

1 scapula, or shoulder blade.
1 clavicle or collar bone.
1 humerus or arm.
1 radius } forearm.
1 ulna }
8 carpal or wrist bones.
5 metacarpal or palm bones.
14 phalanges or finger bones.

The bones of the lower extremity (62) or 31 on each side.

1 os innominatum or hip bone.
1 femur or thigh bone.
1 tibia } leg.
1 fibula }
1 patella or knee-cap.
7 tarsal.
5 metatarsal.
14 phalanges or toes.

The sternum is sometimes said to form several bones, hence the varied numbers of the bones in the skeleton given in different books.

THE BONES OF THE SKULL.

The eight bones of the cranium are so placed as to form a hollow, somewhat spherical receptacle for the brain. They are joined to each other by sutures.

Frontal Bone.—Forming the greater part of the forehead is the frontal bone. The internal surface lodges the anterior lobes of the brain, or that portion said to contain the intellectual centers.

Parietal Bone.—Back of this are two quadrilateral bones called the parietals, which are united by a suture in the middle of the skull called the parietal suture.

Temporal Bone.—Two temporal bones situated at the sides and base of the cranium, are described as having three distinct portions, the squamous, the petrous and the mastoid process. The petrous portion contains the internal ear and the canal leading thereto, and supports the cartilaginous external ear or auricle.

To the mastoid process are attached the sternomastoideus, the splenius capitis and the trachelomastoideus muscles. The squamous portion gives attachment to several muscles concerned in mastication.

Occipital Bone.—The posterior-inferior part of the cranium is formed by the occipital bone. On this are several points of interest. A large foramen (*foramen magnum*) gives passage to the spinal

cord as it passes from the brain into the spinal canal. Anteriorly to the foramen are two articular processes where the skull rests upon the atlas and articulates with it. The posterior surface presents a prominent process of bone called the occipital protuberance to which the ligamentum nuchæ is attached. Curving outward from this on each side are the superior curved lines to which are attached the occipito-frontalis, the trapezius and splenius capitis muscles. Below the superior are the inferior curved lines, and to the space between are attached the complexus, the rectus capitis posticus major and minor and the obliquus superior muscles.

Fig. 35.—Skull, viewed from the left side, showing the principal cranio-metric points. (Gerrish.)

Sphenoid Bone.—The sphenoid, a bat-shaped bone, is wedged in between the bones of the base of the skull, and from the standpoint of the anatomist is very important and interesting, but, having no important muscular attachments need not be given further consideration here.

Ethmoid Bone.—The ethmoid is a small bone that helps to form the nasal and orbital fossæ.

The fourteen bones of the face form the framework to which the muscles of expression are attached as well as some that have to do with mastication and deglutition. They form part of the orbital

and oral cavities and the nose and provide sockets in which the teeth are set.

Malar Bones.—The two malar bones form the prominence of the cheek; the *lachrymal* bones help form the canal for the tear duct;

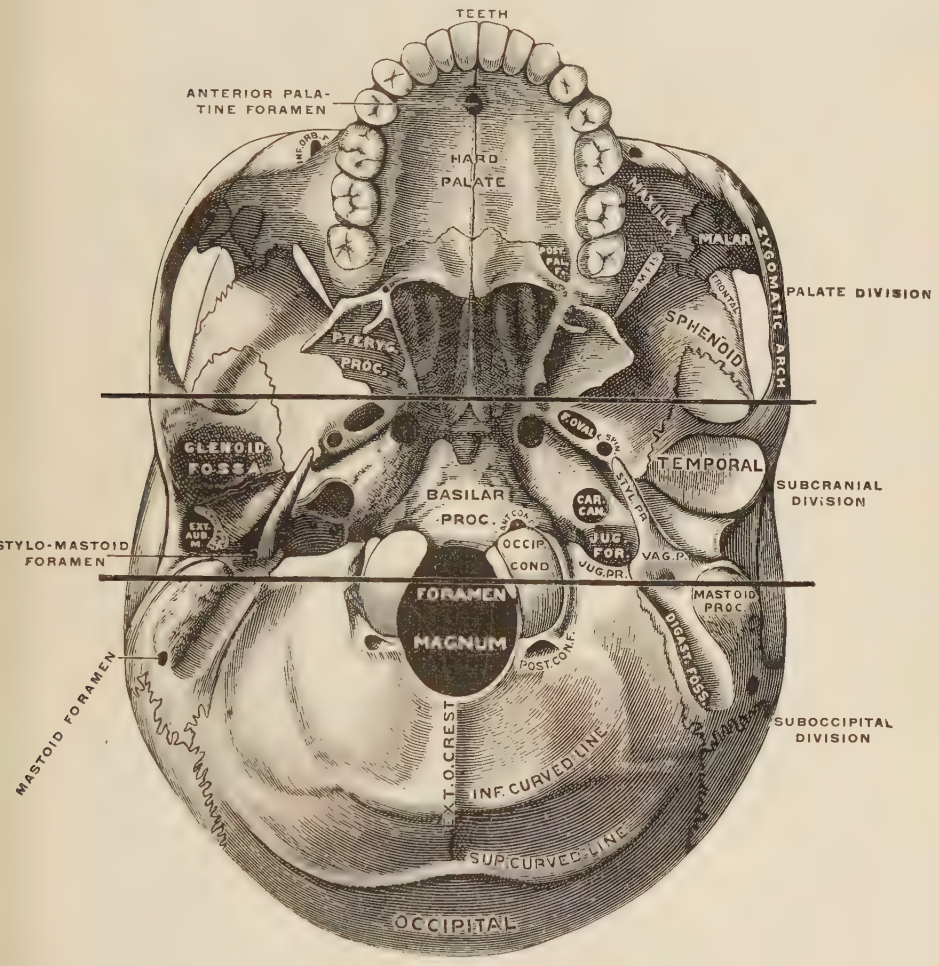


FIG. 36.—Base of the skull, viewed from below, the mandible having been removed. (Testut.)

the *nasal* bones form the upper part of the nose; the *inferior maxillary* or *mandible* is the lower jaw in which are the alveolar processes for the teeth, and to which numerous muscles are attached. The two *superior maxillary* and two *palate* bones form the roof of the mouth, and the former provides sockets for the upper teeth; the

two *turbinated* bones provide the base for a large surface of mucous membrane, while the *vomer* forms the lower and back part of the septum between the two sides of the nose. (Figs. 35, 36 and 37.)

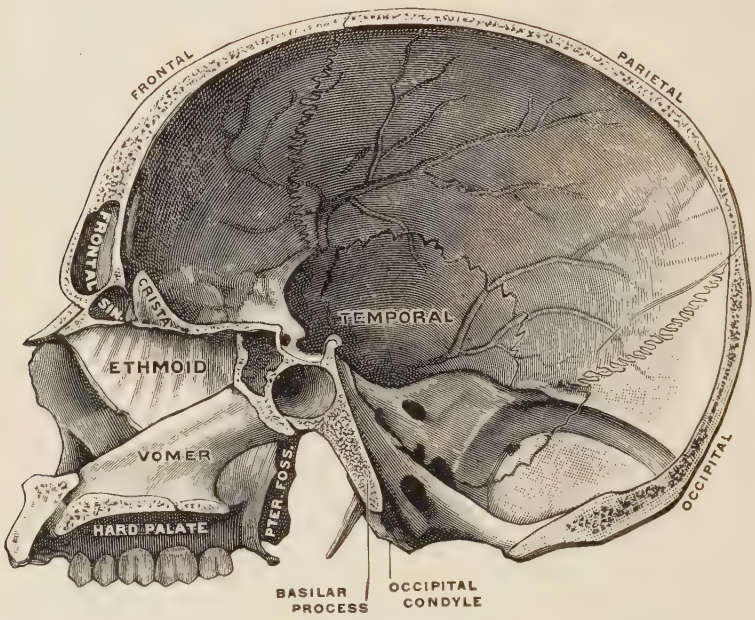


FIG. 37.—Sagittal section of skull, a little to the left of the middle line, the inner surface of the right half. (Testut.)

THE BONES OF THE TRUNK.

The bones of the trunk are arranged to form a receptacle for the thoracic and abdominal viscera, that at the same time gives protection, allows for changes in size and form and provides attachments for the muscles whose actions are essential to their proper functioning. This receptacle is somewhat cylindrical in form, incomplete in the front lower part and made up of the spinal column behind, the sternum in front and the ribs on the front, sides and back.

The Spinal Column.—The spinal column is made up of twenty-six segments to provide flexibility with strength. These segments are vertebræ, either typical or rudimentary, grouped into five divisions. In the neck are seven vertebræ, called cervical; below these are twelve dorsal or thoracic vertebræ, to which the ribs are attached; below these, five lumbar vertebræ, followed by the sacrum and that, by the coccyx.

A *vertebra* is an irregular bone, having a body in front and an arch (neural) behind.

The body is the large solid portion, somewhat like a half-cylinder, with a concave posterior, and convex anterior and lateral surfaces. The weight of the head and trunk, together with that of the upper extremity is borne on the column of bodies.

The neural arch is joined to the body by processes called pedicles. Continuing from the pedicles are flat plates called laminæ, which with the body complete the borders of the vertebral or spinal foramen through which passes the spinal cord. Supported by the pedicles and laminæ are seven bony processes, one spinous posteriorly, two transverse and four articular. On the upper and lower surfaces of the pedicles are notches, which become parts of intervertebral foramina when two vertebræ are joined together. Through these foramina pass the spinal nerves, branching out from the spinal cord.

The spinous process projects backward in the median line at the junction of the laminæ. The transverse processes project outwardly from the sides and the articular processes extend from the roots of the transverse processes. They are in pairs, superior and inferior, facing in opposite directions and articulating with those above and below respectively.

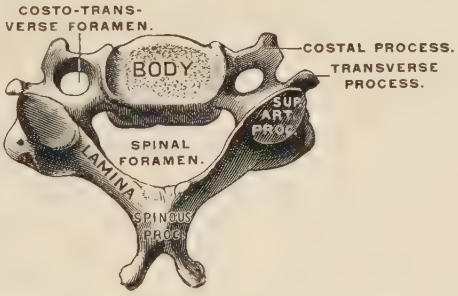


FIG. 38.—Cervical vertebra, viewed from above. (Testut.)

This description is of a typical vertebra, and with the exception of a few vertebræ, all these parts are found on every one, but there are distinguishing variations in the different regions.

In the cervical or neck region the seven vertebræ have to provide for a greater amount of movement than elsewhere, so there are certain differences in structure. The bodies are smaller and flatter; on the upper surface are lateral lips; on the under surface, an anterior lip; the transverse processes are forked or bifid, with foramina for the passage of the vertebral artery; and the spinous processes are bifid and nearly horizontal. The third, fourth, fifth and sixth are typical, but the first, second and seventh are peculiar.

The first cervical vertebra or *atlas*, is directly under the occiput, articulating with it. It has no body or spinous process, and allows the greatest possible freedom of motion between the head and the

spinal column. Two arches, dorsal and ventral, connect two lateral masses. On the upper surface of these masses are large articular

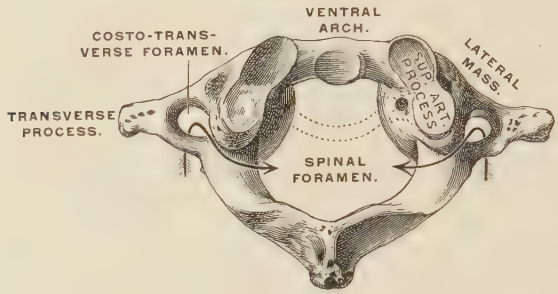


Fig. 39.—The atlas, viewed from above. (Testut.)

surfaces upon which the head rocks back and forth, in the occipito-atloid articulation. The articular facets on the under surface of the lateral masses are for the union with the second cervical vertebra,

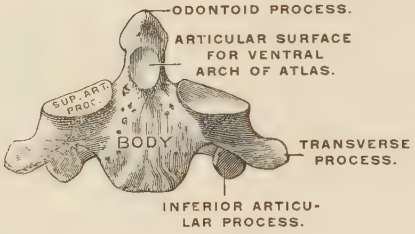


Fig. 40.—The axis, front view. (Testut.)

the *axis*. The *axis* has a large strong body, on which is fused the body of the atlas, here serving as a pivot around which the atlas carrying the head may rotate. This process is the odontoid (tooth-like).

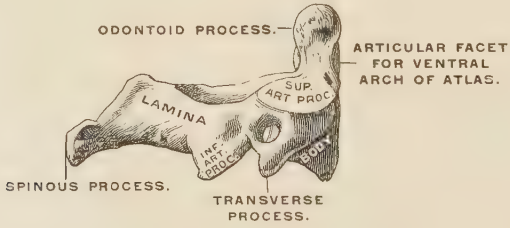


Fig. 41.—The axis, its right side. (Testut.)

The seventh cervical vertebra has a long spinous process that is not bifid. It is very prominent, hence its name, the *vertebra prominens*, serving as a landmark.

The next group is the *thoracic* or *dorsal vertebræ*, distinguished primarily by facets on the bodies for articulation with the head of the rib, and facets on the transverse processes for articulation with the tubercle of the ribs. Usually the facets on the bodies are on the upper and lower borders, so that with the intervertebral car-

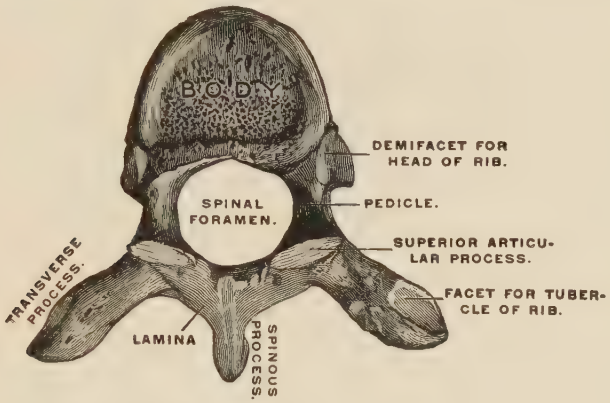


FIG. 42.—A thoracic vertebra, upper surface. (Testut.)

tilage between the bodies, the head of a rib may set into a sort of socket. The spinous processes project downward and overlap, especially in those near the middle of the group, while the laminæ also overlap. The first and last of this group resemble those of the contiguous groups above and below. The overlapping of spines

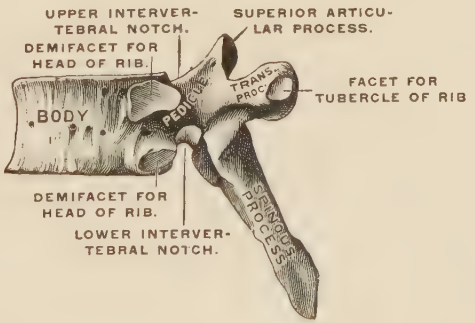


FIG. 43.—Thoracic vertebra, seen from the left side. (Testut.)

and laminæ limits extension of the spine very markedly, but does not much interfere with flexion and rotation.

The *lumbar vertebræ* are large and heavy looking, having large oval bodies, long transverse processes and square strong looking spinous processes. They have neither bifid spines nor foramina

in the transverse processes, which would distinguish them from the cervical vertebræ, nor articular facets on the body and transverse processes, which distinguishes them from the thoracic group.

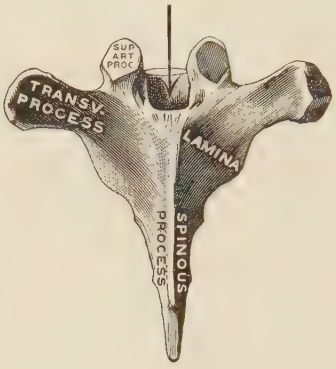


Fig. 44.—Thoracic vertebra, viewed from behind. (Testut.)

A large number of ligaments and muscles are attached to the vertebræ, connecting the spine to the head, to the trunk, to the upper and lower extremities.

The *sacrum* articulates with the last lumbar vertebra and gives support to the spine as a whole. It is a modification of vertebræ, five seemingly being fused together, and lacking various character-

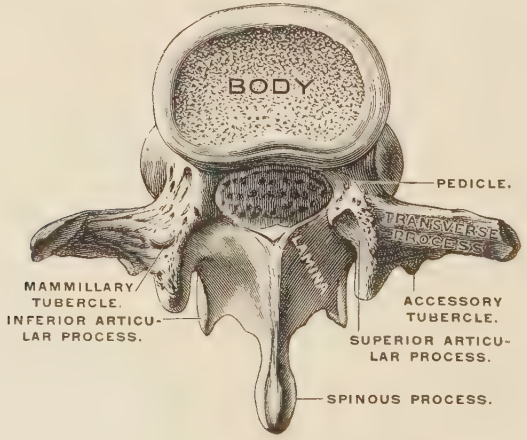


Fig. 45.—Lumbar vertebra, viewed from above. (Testut.)

istics of the typical vertebra. The bone is triangular in shape, widest above and tapering below, where it articulates with the upper bone of the coccyx. The sacrum lies obliquely, with the upper

surface inclined forward, and forming an acute angle with the last lumbar vertebra. The upper part is called the promontory, with

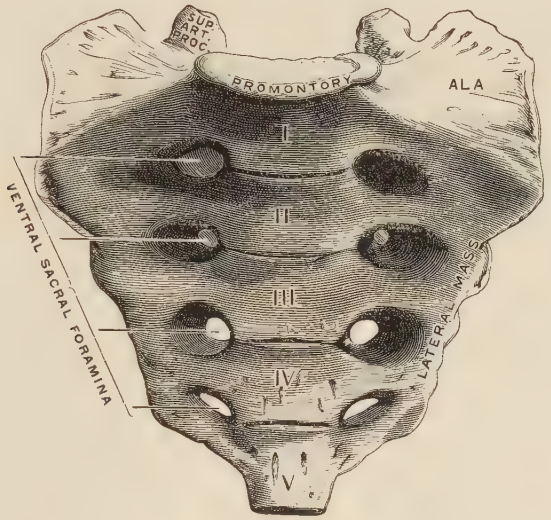


Fig. 46.—The sacrum, ventral view. (Testut.)

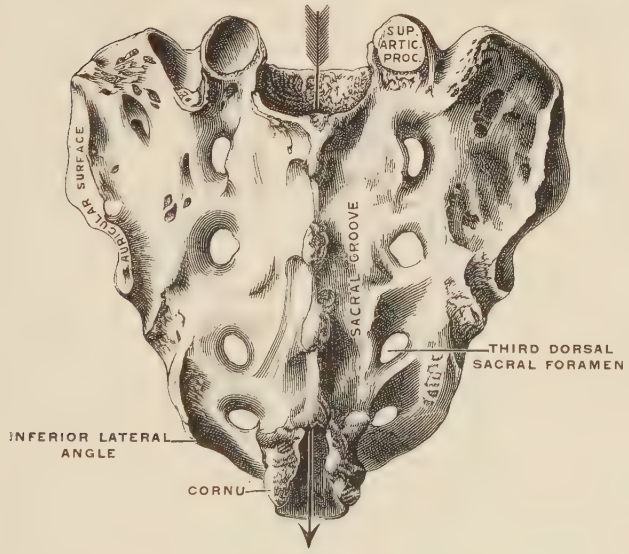


Fig. 47.—The sacrum, dorsal view. (Testut.)

the alæ or wings on the sides. On each side are four large foramina, going through from front to back for the passage of the sacral

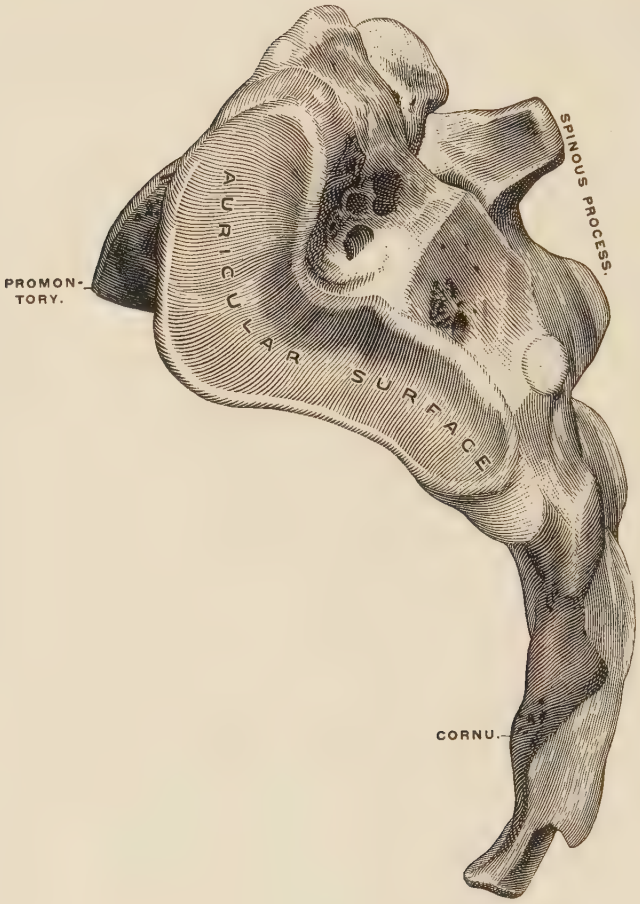


FIG. 48.—The sacrum, its left side. (Albinus.)

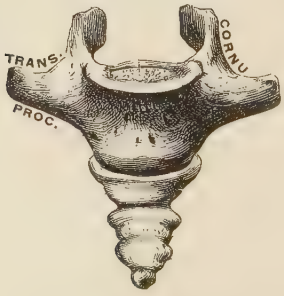


FIG. 49.—The coccyx, ventral surface. (Testut.)

nerves. The front of the bone is relatively smooth, but the dorsal aspect presents much roughness for the attachment of muscles and ligaments. The rudimentary spinous processes form a rough ridge. Laterally, are two ear-shaped articular surfaces, called the *auricular surfaces,* which articulate with the ilium. This articulation of the two bones completes the bowl-shaped cavity known as the bony pelvis.

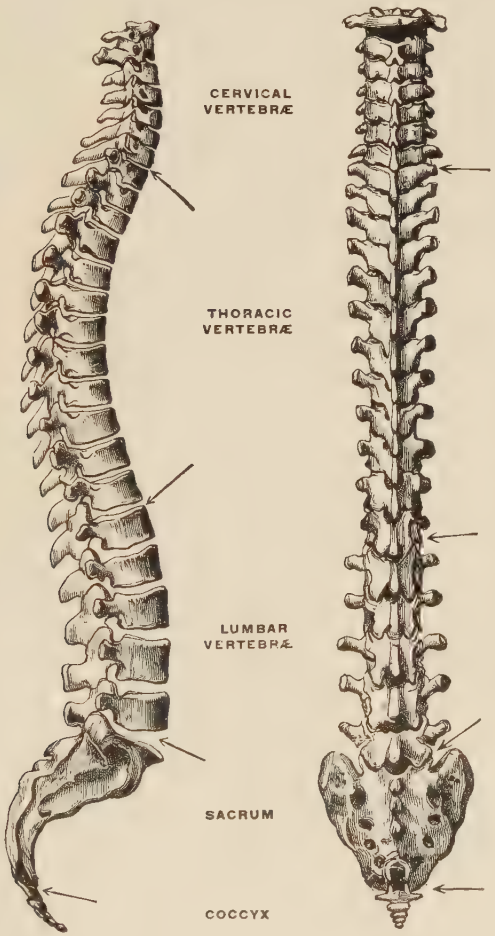


FIG. 50.—The spinal column, right lateral view and dorsal view. (Testut.)

The *coccyx* consists of a variable number of small bones, rudimentary vertebræ, of triangular shape, tapering downward. In early life there may be from three to five of these, but later they are apt to fuse together. They serve for the attachment of several large muscles and aponeuroses.

The Spine as a Whole.—The spinal column is the central axis of the body, and is in the median line and posterior part of the trunk. It supports the head, the ribs and the upper extremity. The weight of these parts is transmitted through the spinal column to the lower extremities through the hip-bones with which the sacrum articulates.

The average length is 27 or 28 inches, of which about a quarter is made up of the fibrocartilaginous intervertebral disks. The view from the side shows four curves from before backward. Convex forward in the cervical and lumbar regions; convex backward in the thoracic and sacral regions. The two latter are present at birth, but the other two are developed as the child assumes an upright position. The shape of the bodies determines the sacral and thoracic curves, but the intervertebral disks determine the extent of the curve in the other two regions. These curves add much to the strength and elasticity of the column, and lessen jars. No lateral curve normally exists.

From the standpoint of correct posture the relations of the different parts of the spinal column are exceedingly important. As the muscles attached to the spine connect it with every other part of the body, movements elsewhere have an influence upon its position, producing lateral deviations more or less temporary. At the junction of the cervical and dorsal spines there is a dividing point between several important muscles, with resulting weakness. This feature is much more marked at the junction of the dorsal and lumbar spines for the same reason and the additional fact that there a fixed part, the thorax joins the most movable part, the lumbar spine. A long leverage above and below with the width of the spine less than in either locality contributes to the weakness (Fig. 50).

Note.—This is easily demonstrated by holding the carcass of a fowl with one hand on the upper part, the other hand on the lower part of the trunk and bending the body backward. The spine gives way at the dorso-lumbar junction with startling ease.

The Sternum.—The sternum or breast bone is on the front wall of the thorax, connecting with the ribs and the clavicle. It is a long thin bone, wider above than below, having at the lower end a prolongation of cartilage called the *xiphoid* or *ensiform cartilage* or process. The upper part of the bone is thicker and wider and is called the *manubrium* or "handle." It is united to the lower part by fibrocartilage and remains distinct through life. The lower part, the *gladiolus* or "little sword" in early life consists of four segments which later unite into one piece.

The *manubrium* has a notch on its upper surface ("interclavicular notch") and two articular surfaces on the lateral angles for articulation with the clavicles. At the widest part on the side, are articular facets for its union with the cartilage of the first rib. At the junction of the manubrium and gladiolus is a transverse ridge that

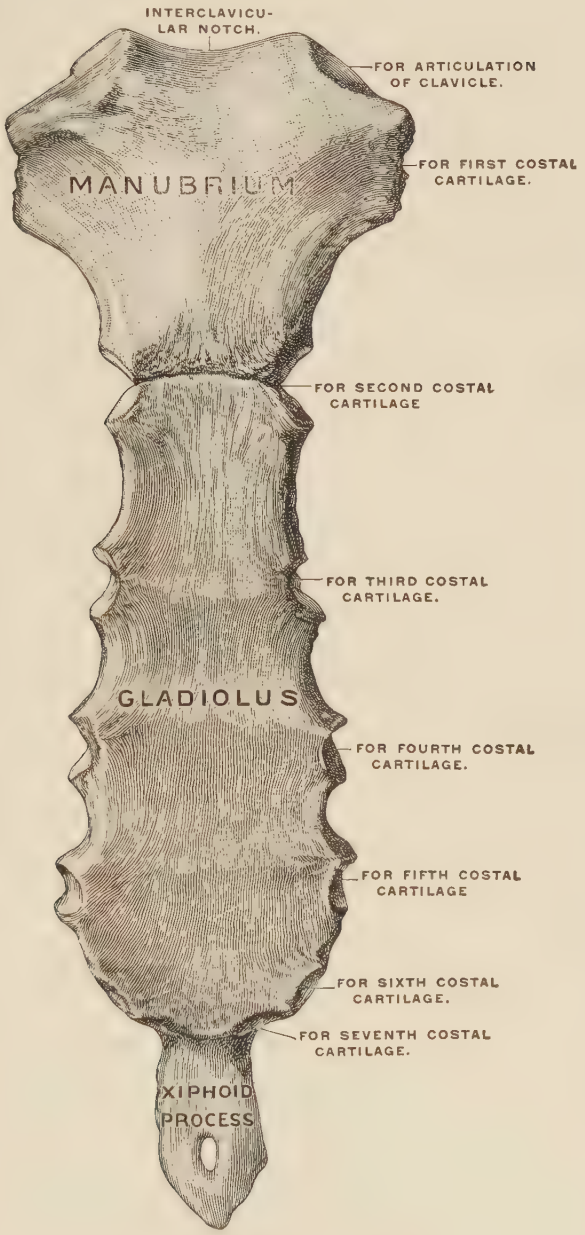


FIG. 51.—The sternum, ventral aspect. (Spalteholz.)

serves as a landmark in locating the valves of the heart. Articular facets laterally give attachment to the second rib, while the next five articulate with the gladiolus. Thus seven ribs are directly joined to the sternum.

The muscles attached to the sternum are, pectoralis major, sternomastoideus, rectus abdominis, the aponeurosis of the transversus abdominis and obliquus internus abdominis, the sternohyoid, the sternothyroid, the triangularis sterni, the internal intercostals and the diaphragm.

The Ribs.—Twelve pairs of ribs form the larger part of the walls of the thorax, prolonged at the front end by plates of cartilage, the *costal cartilages*, which serve as buffers and increase elasticity. The upper seven pairs of ribs are attached directly to the sternum and are considered true ribs (or sternal ribs) while the next three being indirectly attached to the sternum are called false (or asternal)

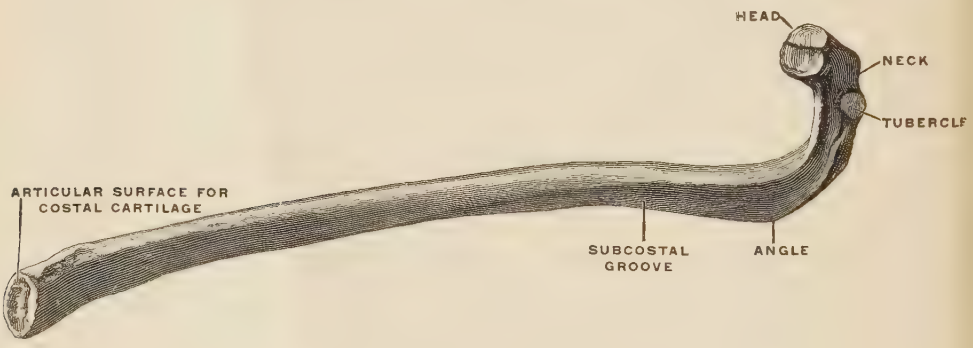


FIG. 52.—The sixth rib of the right side viewed from the middle line of the body. (Spalteholz.)

ribs, and the last two pairs are attached to the vertebræ only and are called "floating ribs."

The length of the ribs increases from the first to the eighth then decreases to the twelfth.

A rib is a "long bone," having a shaft and two extremities. The middle eight ribs are typical, but the first two and last two are peculiar. At the vertebral end of a typical rib is the enlarged *head* which is joined by a constricted neck to the shaft. The *head* articulates with the bodies of the vertebræ. Just where the neck joins the shaft is a prominence of bone called the *tubercle*. This articulates with the transverse process of a vertebra. The shaft begins at the tubercle and extends to the sternal end where a cup-like cavity receives the costal cartilage.

The shaft of the rib is curved in three directions. Looking at the back of the thorax it is seen that there is a relative fulness to the

curve of the ribs, and that where they begin to form the side wall of the chest a sudden bend is made in the curvature. This bend is the *angle* and it takes place at a greater distance from the spine in the lower ribs as they proceed downward. The curvature of the front end is flatter. In addition to these curves on the flat, the shaft of the lower ten ribs at the angle is curved on the horizontal axis so if the rib rests upon the lower border of the shaft the vertebral end curves upward. This curve increases from the third to the seventh ribs, then decreases to the twelfth. This twisting is of great importance in providing for an increase of the lateral and antero-posterior diameters of the thorax in respiration.

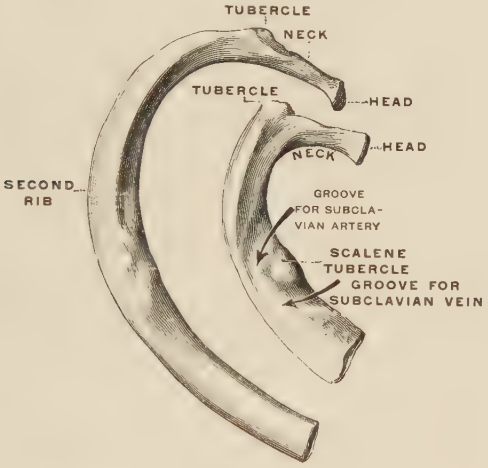


FIG. 53.—The first and second ribs of the right side, viewed from above. (Testut.)

Peculiar Ribs.—The first rib is short, broad and so placed that the surfaces face up and down. It affords attachment to the scalenus anticus and medius muscles, and to the first digitation of the serratus magnus muscle.

The second rib is longer and lacks the curve on the horizontal axis. It gives attachment to the scalenus posticus and to the second and third digitations of the serratus magnus muscle.

The scaleni being muscles of inspiration act by raising these two upper ribs thus providing a firm base for the elevation of the other ribs by the intercostal muscles.

The eleventh and twelfth ribs are short and lack several of the characteristics of a typical rib, as tubercle and angle.

The costal cartilages are hyaline cartilage which prolong the ribs at the sternal ends, fitting into cup-like depressions on the shaft and the first seven articulating with the sternum. Their direction is upward and inward and the length increases to the seventh rib.

The cartilages of the eighth, ninth and tenth ribs unite with each other and the upper part is joined to the cartilage of the seventh rib. The cartilages of the eleventh and twelfth ribs form smooth ends. The costal cartilages give attachment to most of the muscle mentioned above as being attached to the sternum.

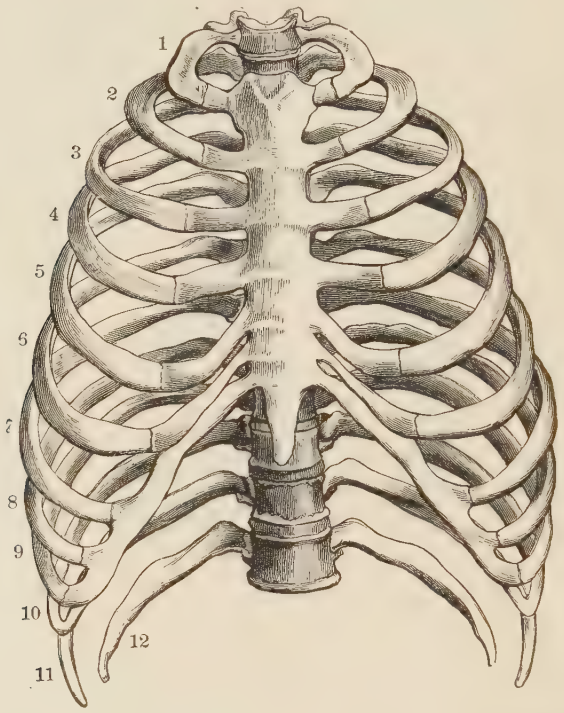


FIG. 54.—The skeleton of the thorax, front view. (Testut.)

The Thorax.—The thorax is a bony cage, roughly cone-shaped, with the top formed by the first rib facing forward and upward. The much larger base is formed by the edges of the lower six ribs converging to the xiphoid cartilage and forming the *subcostal angle.*

NOTE.—Look up the studies made at the Central School of Hygiene at the Y. W. C. A., New York, in reference to the significance of the width of the subcostal angle as regards mental and vital ability.

The backward curve of the ribs forms a broad furrow on the back, each side of the spinal column, the *vertebral groove* in which rests some of the erector spinæ group of muscles. The back of the thorax is flatter than the front and allows the supine position in man, as distinguished from the rounded backs of quadrupeds.

The bodies of the vertebræ encroach upon the cavity of the thorax

so the inside diameter is less than that taken externally. As far down as the seventh or even lower, the ribs are increasingly more oblique. This makes the intercostal spaces wider at the side than at the back. In inspiration they are wider than after expiration thus increasing the capacity of the thorax.

At birth the thorax resembles that of quadrupeds more than that of an adult human being, being more barrel-shaped and less broad in the transverse direction. The angles have not been developed and the ribs are less curved.

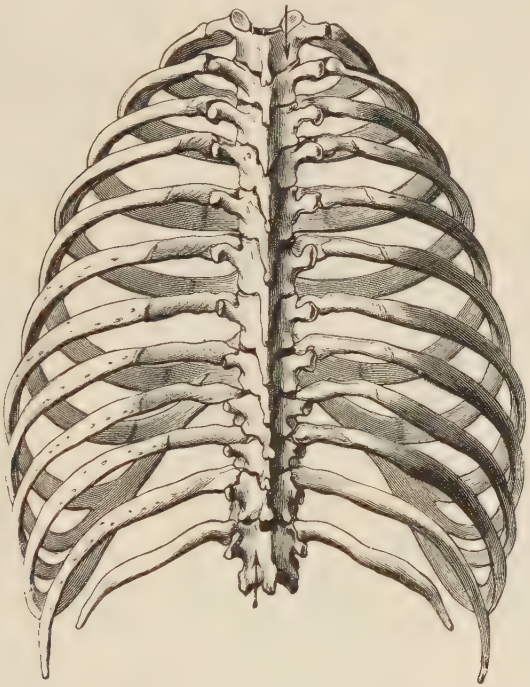


FIG. 55.—The skeleton of the thorax, dorsal view. (Testut.)

The thorax contains the organs of respiration and circulation, and not only protects them, but allows the movements necessary to their proper functioning. While each rib and vertebra has but a small range of motion, the aggregate is considerable.

Many muscles, moving the arms, trunk and head and giving support to the abdominal viscera, are attached to the thorax.

The Hyoid.—The hyoid is a small, light, somewhat horseshoe-shaped bone in the front part of the neck below the chin. To it the tongue and many muscles of deglutition are attached.

THE UPPER EXTREMITY.

The upper extremity consists of the arm, forearm and hand, connected to the trunk by the shoulder girdle. This consists of the clavicle and scapula.

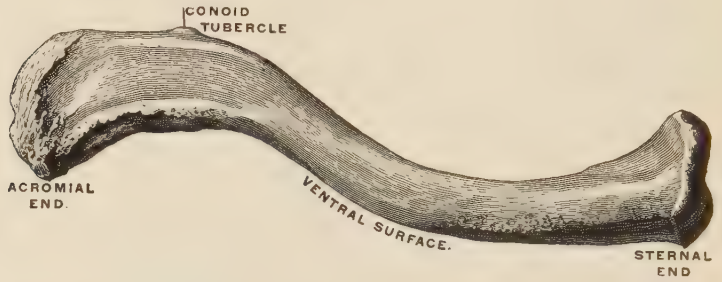


FIG. 56.—The right clavicle, upper surface. (Spalteholz.)

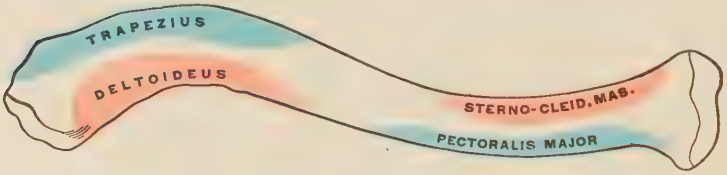


FIG. 57.—Areas of muscular attachment, upper surface of right clavicle. (Gerrish.)

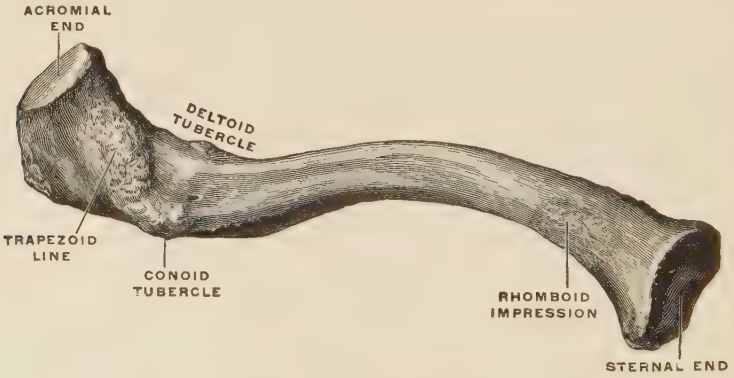


FIG. 58.—The right clavicle, under surface. (Spalteholz.)

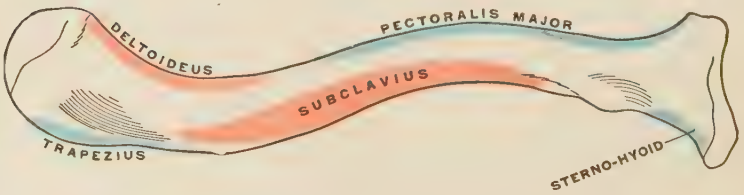


FIG. 59.—Areas of muscular attachment, lower surface of right clavicle. (Gerrish.)

The Clavicle.—The clavicle or collar-bone is a long bone having a shaft and two extremities. It is curved like the italic letter *f*, and extends across the upper part of the chest, horizontally from the notch on the manubrium to the acromion process of the scapula, articulating with these two processes. The inner two-thirds is cylindrical in form, while the outer third is flattened from above downward and curves backward. The shaft of the bone presents on the superior and anterior aspect of the inner half a rough place for the attachment of the sternomastoideus, and below, one for the pectoralis major. The posterior sternal surface gives attachment to the sternohyoid muscle. On the outer third are rough places on the superior surface for the deltoid muscle in front and the trapezius muscle behind.

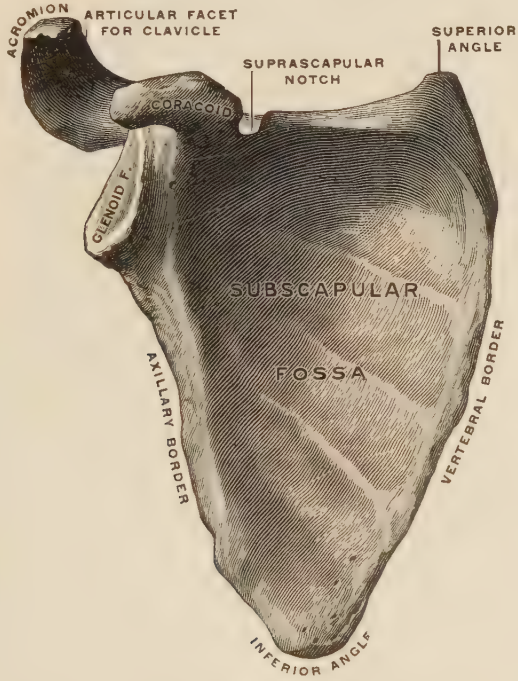


FIG. 60.—The right scapula, ventral view. (Spalteholz.)

The inferior surface at the sternal end presents the rhomboid impression for the attachment of the rhomboid ligament, and the subclavian groove for the subclavian muscle.

Throughout the greater part of its length the clavicle is subcutaneous and its outline may be followed by the finger. The extent of the muscles attached to it may be felt during their contraction. This method of studying muscles should be used whenever possible.

The Scapula.—The scapula or shoulder-blade is a large flat bone, triangular in shape, presenting three angles, external, superior and inferior; three borders, superior, vertebral and axillary; and two surfaces, dorsal and ventral. It extends from the second to the seventh ribs, on the posterior wall of the thorax and from its articulation with the clavicle at the peak of the shoulder to within 2 inches of the spine. The lower border of the inferior angle may be used to locate the seventh thoracic spine as it is in a horizontal line with the latter.

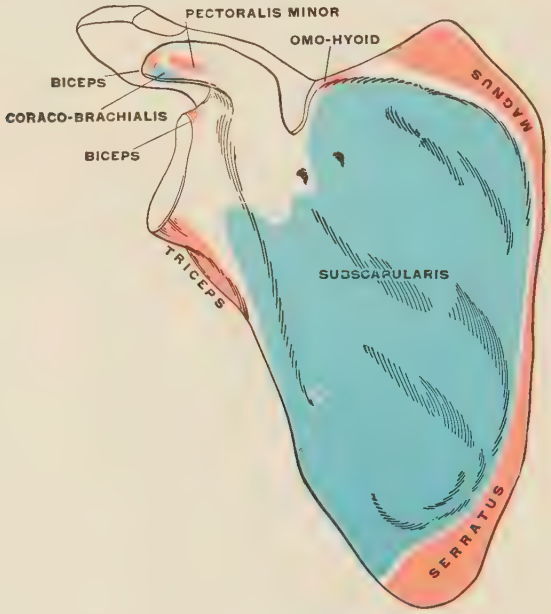


FIG. 61.—Areas of muscular attachment, ventral surface of right scapula. (Gerrish.)

The external angle or head has an articular surface, the glenoid fossa, for articulation with the humerus. Projecting from it toward the front is a beak-like process, the coracoid process. The ventral surface shows a shallow fossa, with several ridges crossing it, for the reception of the subscapular muscle. Along the vertebral border of this surface is a rough ridge for the serratus magnus muscle.

The dorsal surface presents a prominent ridge, the *spine*, which passes from the vertebral border, about one-third of the distance down, going across the bone diagonally upward, becoming heavier and wider, until near the external angle it leaves the surface and continues as a broad rough prominence, the acromion process. The posterior free border of the spine is thick and curved. It is called the crest, with upper and lower lips.

Above the spine is a fossa, the supraspinous, giving attachment to the supraspinatus muscle. The surface below the spine, the infraspinous fossa, is depressed, and gives attachment to the infraspinatus muscle. To the upper lip of the crest is attached the trapezius muscle, while to the lower lip is attached the deltoid muscle. The external or axillary border gives attachment above to the teres minor, and below to the teres major muscles. The internal or vertebral border of the dorsal surface gives attachment above to the rhomboideus minor and below to the rhomboideus major muscles. The superior angle and the uppermost part of the

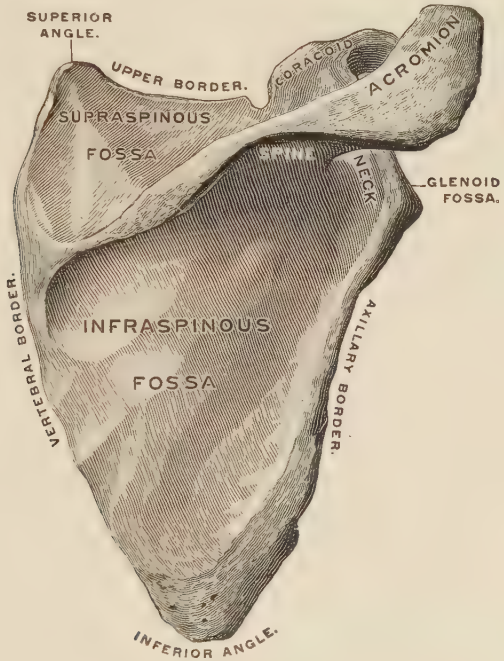


FIG. 62.—The right scapula, dorsal view. (Spalteholz.)

vertebral border gives attachment to the levator anguli scapulæ, while the inferior angle usually has the latissimus dorsi muscle attached. The coracoid process on the external angle is covered with an aponeurosis which gives attachment to the pectoralis minor, the coraco-brachialis and the short head of the biceps muscle. Above the glenoid fossa, is a rough impression for the tendon of the long head of the biceps muscle, while below the fossa the long head of the triceps muscle is attached. The glenoid fossa, covered with cartilage in the recent state looks upward, outward and forward. The superior border of the scapula is concave, extending from the

superior angle to the base of the coracoid process. It presents the suprascapular notch, through which passes the suprascapular nerve. To the border adjacent, the omohyoid muscle is inserted. This completes a total of seventeen muscles which arise from the scapula, passing in every direction, anchoring it and guarding the shoulder-joint, besides providing for movements of adjacent parts.

The only bony connection of the shoulder girdle with the trunk is at the sterno-clavicular articulation.

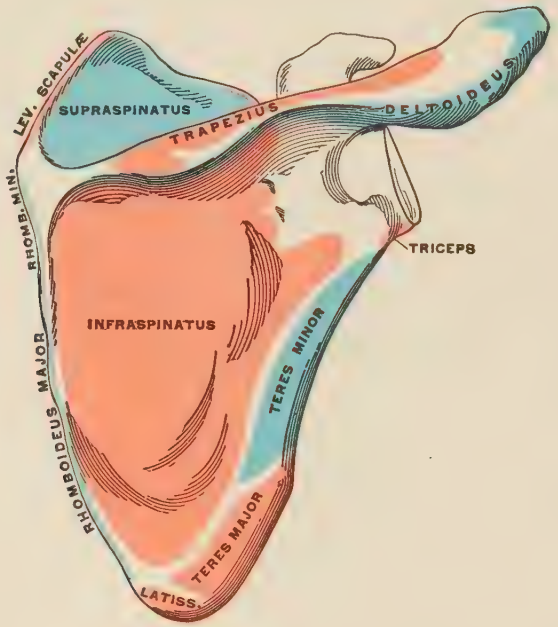


FIG. 63.—Areas of muscular attachment, dorsal surface of right scapula. (Gerrish.)

The Humerus.—The humerus (brachium) or the bone of the arm is a long bone with a shaft and two extremities. The upper extremity presents a rounded head, covered with cartilage in the recent state, and articulating with the glenoid fossa of the scapula. The head is directed upward, inward and backward, at an angle of about 130 degrees. Just below the head is a constriction of the bone which is called the "anatomical neck," in distinction from the "surgical neck" below the tuberosities. (The surgical neck is so-called for convenience in designating the locality in case of fracture). The anatomical neck gives attachment to the capsular ligament of the shoulder-joint. Below this are two prominences separated by a groove, the bicipital groove. The larger and outer prominence is the greater tuberosity; the smaller and inner, the lesser tuberosity. On the latter is inserted the subscapularis muscle. On the greater

tuberosity are three facets, one being above, the other two posterior. To the upper facet is attached the supraspinatus muscle; to the middle facet the infraspinatus muscle and to the lowermost facet the teres minor muscle.

Through the bicipital groove runs the tendon of the long head of the biceps muscle to be attached above the glenoid fossa. The groove has two lips, to the inner of which the teres major muscle is attached, and on the floor of the groove and to the inner lip the latissimus dorsi muscle is attached. To the outer and anterior lip, the tendon of the pectoralis major muscle is attached.

The shaft of the humerus is cylindrical above, flattening sideways in the lower part. The bone has three surfaces, internal, external and dorsal, separated by internal, external and anterior borders. The internal border has a rough place near its center for the coraco-brachialis muscle. The lower part of the border becomes the internal supracondylar ridge, ending in the internal condyle. The external border extending downward from the greater tuberosity is more marked at the lower end, becoming the external supracondylar ridge, to which in the upper two-thirds is attached the brachio-radialis and below that the extensor carpi radialis longus muscle. The anterior border begins at the outer lip of the bicipital groove, and passes down to between the capitellum and trochlea. Just above the center of the bone on the external surface is a very rough impression for the attachment of the deltoid muscle. Below this, passing across the external border, a groove, the musculo-spiral groove, winds around the shaft of the bone downward and forward. In the groove lies the musculo-spiral nerve. Above the groove, on the dorsal surface of the humerus the external head of the triceps muscle is attached, while to the surface below, the internal head is attached. To the lower half of the anterior surface is attached the brachialis muscle.

The lower extremity of the humerus is flattened from before backward, and curved forward, with prominent processes, the condyles, on each side. These are subcutaneous. The more prominent, the *internal* condyle gives attachment to a group of flexor and pronator muscles, namely the flexor carpi radialis, flexor carpi ulnaris, palmaris longus, flexor sublimis digitorum and pronator teres. The *external* condyle is less prominent and gives attachment to a group of *extensor* muscles and supinators, namely, the extensor carpi radialis brevis, extensor communis digitorum, extensor minimi digiti, extensor carpi ulnaris, supinator and the anconeus.

Between the condyles is an articular surface, divided into two parts. The larger inner surface is the trochlea (pulley), which articulates with the head of the ulna. Above this in front is the coronoid fossa receiving the coronoid process of the ulna in forced flexion of the forearm. Back of the trochlea is the olecranon fossa,

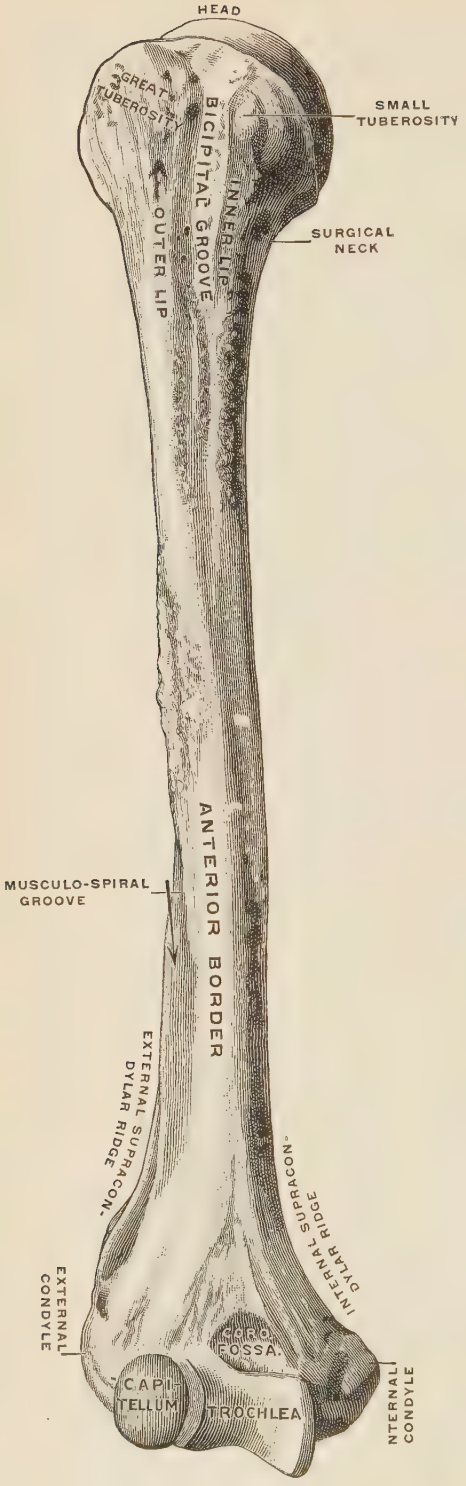


FIG. 64.—The right humerus, front view. (Testut.)

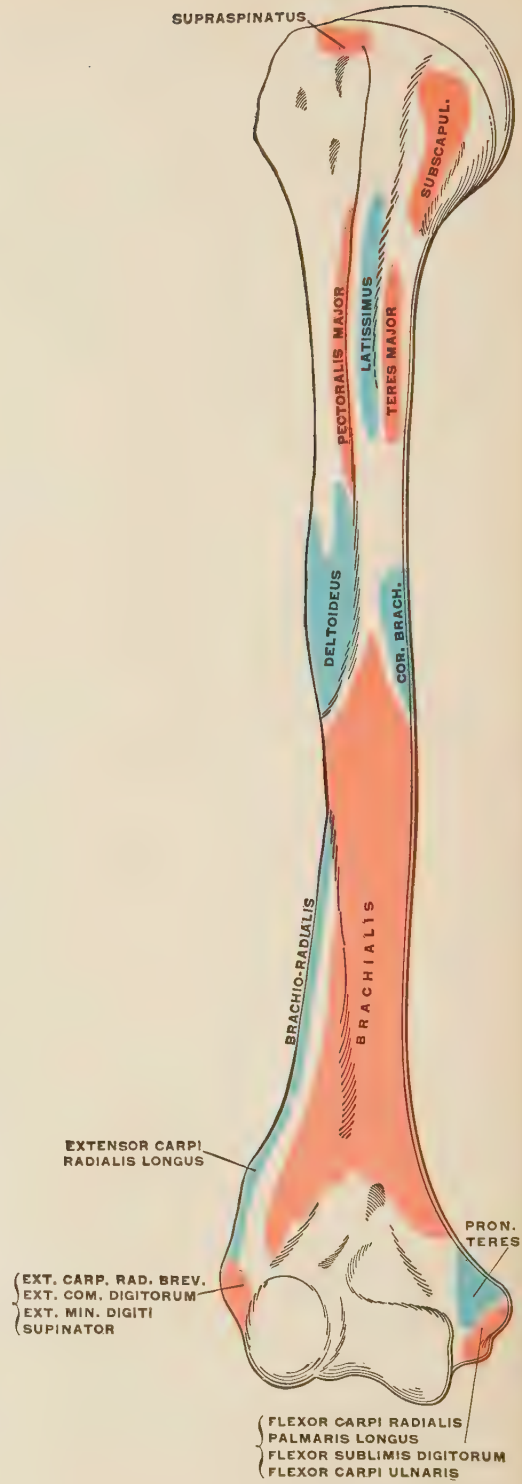


FIG. 65.—Areas of muscular attachment, ventral aspect of right humerus. (Gerrish.)

FIG. 66.—The right humerus, rear view. (Testut.)

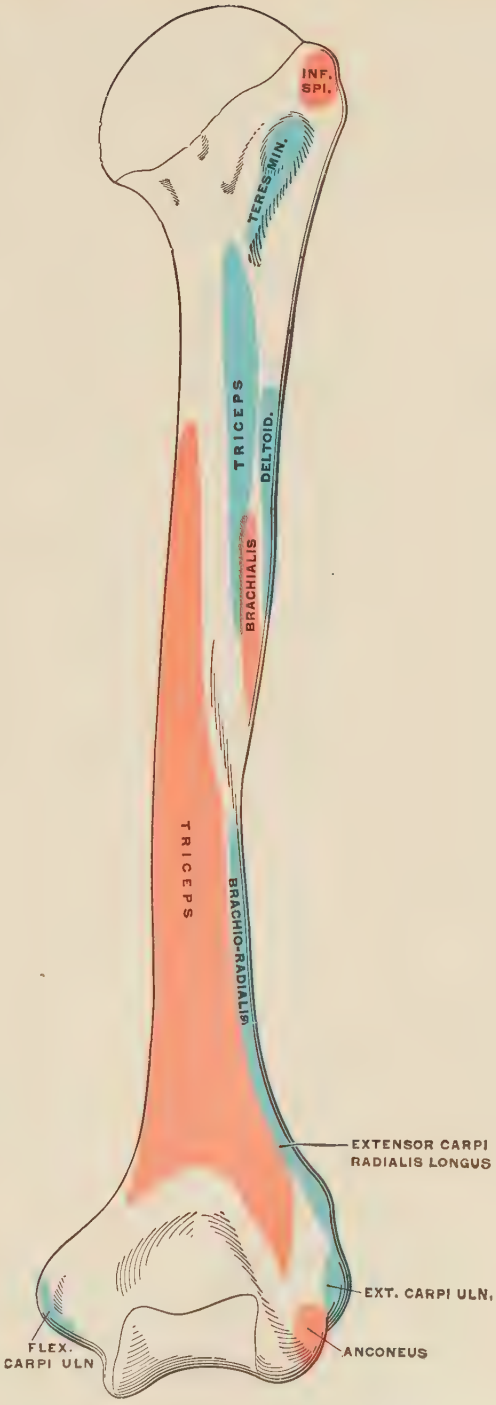


FIG. 67.—Areas of muscular attachment, dorsal surface of right humerus. (Gerrish.)

receiving the olecranon process of the ulna in extension of the forearm. The small inner part of the articular surface is the capitellum, for articulation with the head of the radius.

The Bones of the Forearm, the Radius and the Ulna.—The *ulna* is the longer and is placed on the inner side. It presents a shaft and two extremities. The upper part is thickest and shows an articular

FIG. 68.—The bones of the right forearm, ventral view. (Testut.)

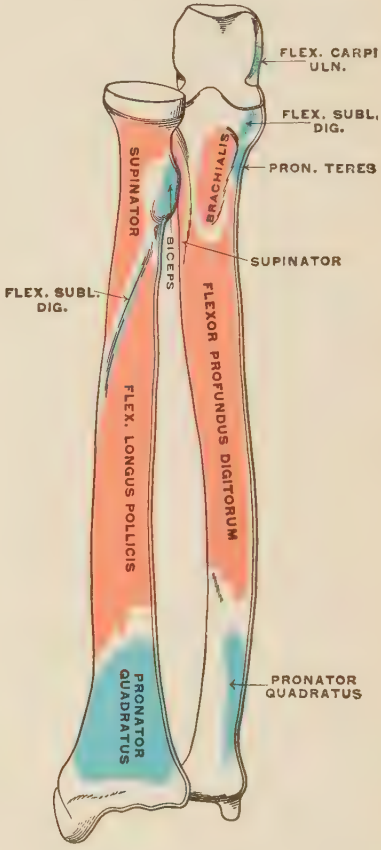


FIG. 69.—Areas of muscular attachment, ventral aspect of the radius and ulna. (Gerrish.)

surface, curved forward called the greater sigmoid cavity. This articulates with the trochlea of the humerus. Below this is the coronoid process which gives attachment to the brachialis and to slips from the flexor sublimis digitorum, pronator teres and the flexor longus pollicis muscles.

Posteriorly is the heavy olecranon process, the highest part of

the bone, to which the triceps muscle is attached on the upper surface. The olecranon is mostly subcutaneous and is the most prominent part of the elbow.

Continuous with the greater sigmoid cavity, on the outer side is a smaller articular surface, the lesser sigmoid cavity, in which the head of the radius turns in pronation and supination of the forearm.

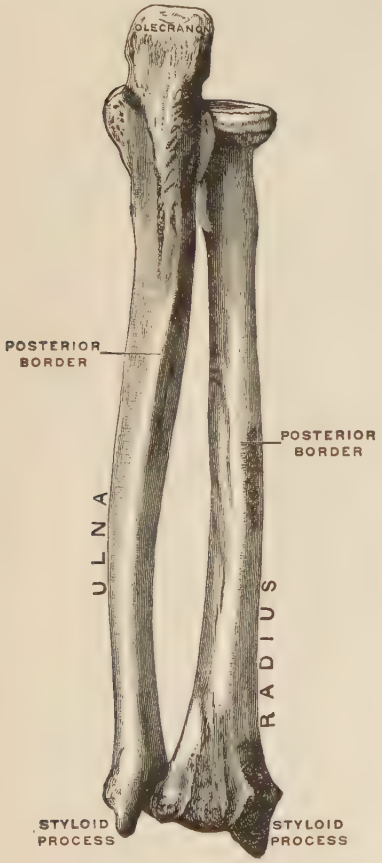


FIG. 70.—The bones of the right forearm, dorsal view. (Testut.)

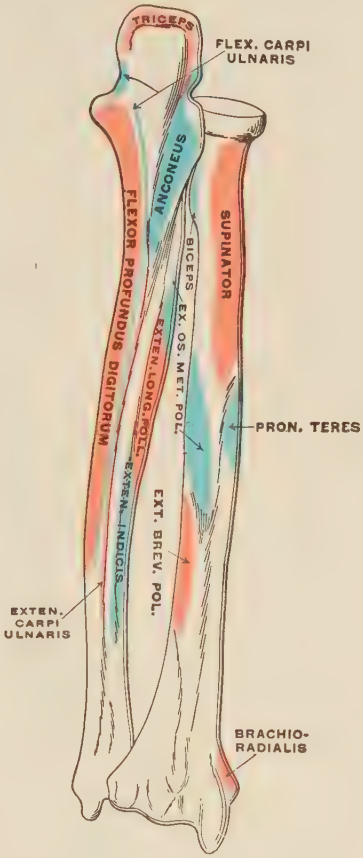


FIG. 71.—Areas of muscular attachment, dorsal aspect of radius and ulna. (Gerrish.)

The shaft becomes rounded as it descends, though the upper part is triangular, showing definitely three borders and three surfaces. The external or interosseous border gives attachment to the interosseous membrane, and divides into two lines above, passing to the ends of the lesser sigmoid cavity, and enclosing a triangular space on which the supinator muscle is attached. The anterior surface

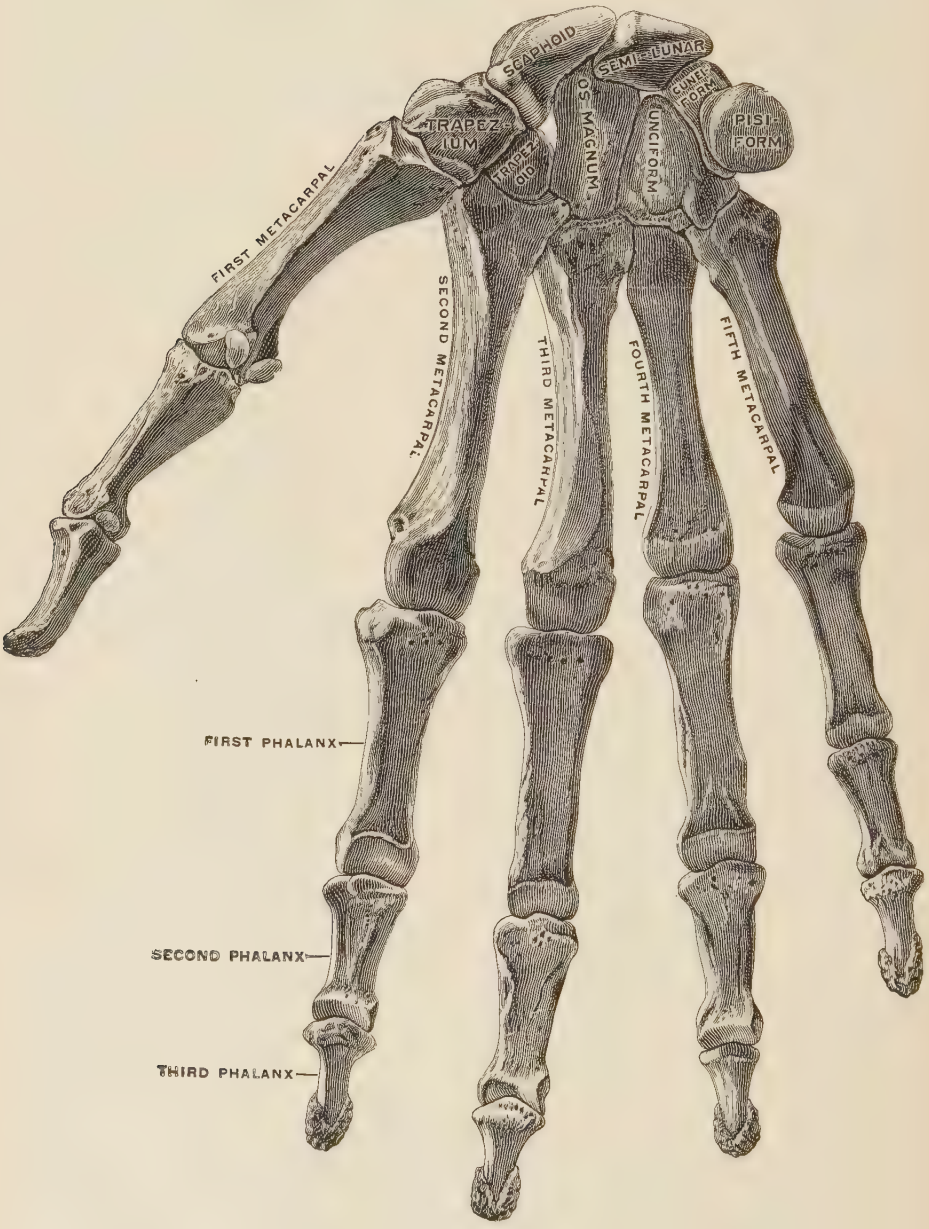


FIG. 72.—The bones of the right hand, palmar aspect. (Spalteholz.)

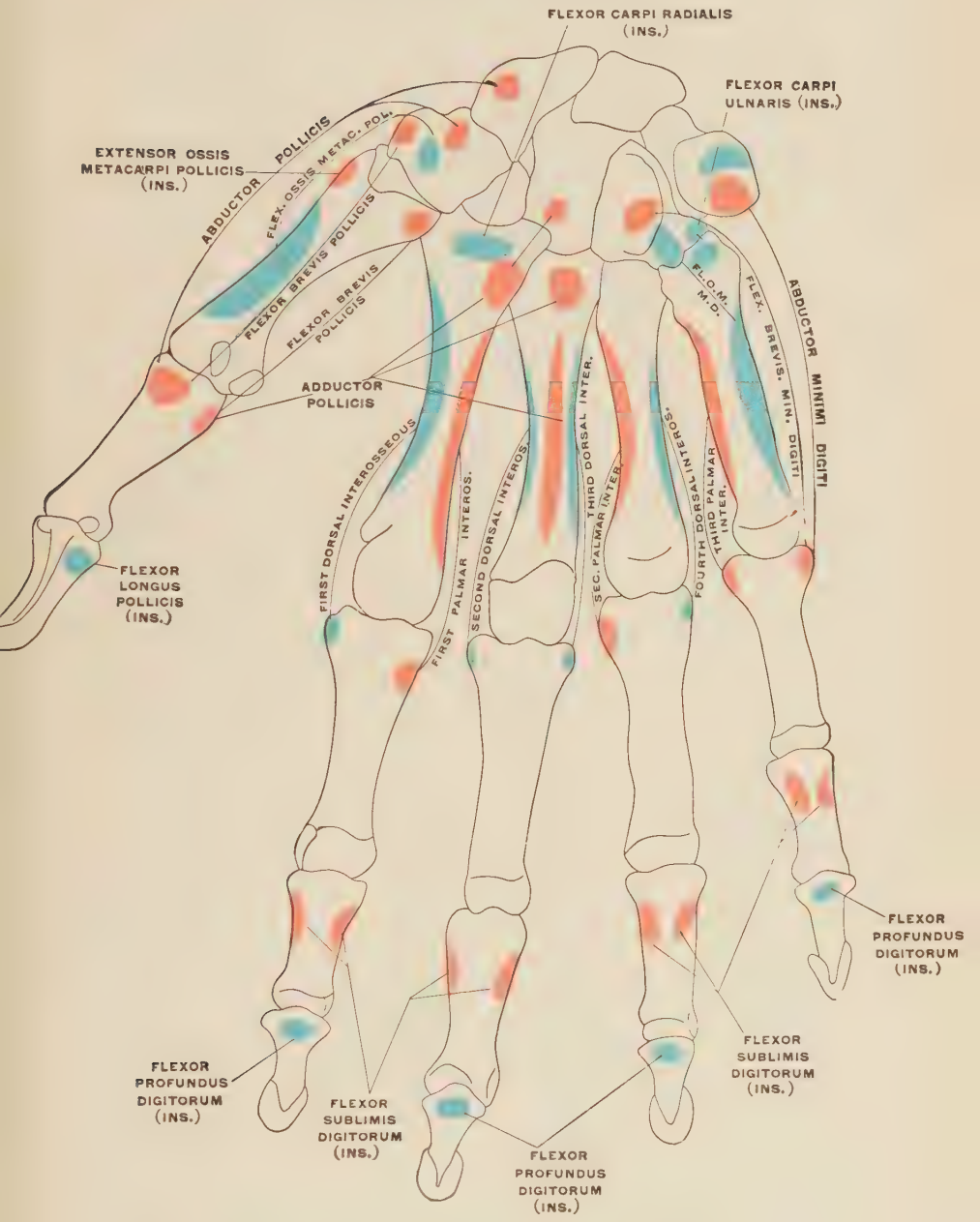


FIG. 73.—Areas of muscular attachment on the palmar surface of the bones of the hand. Where the areas of origin and insertion are both presented they are in the same color. INS., insertion; FL.O.M.M.D., flexor ossis metacarpi minimi digiti. (Gerrish.)

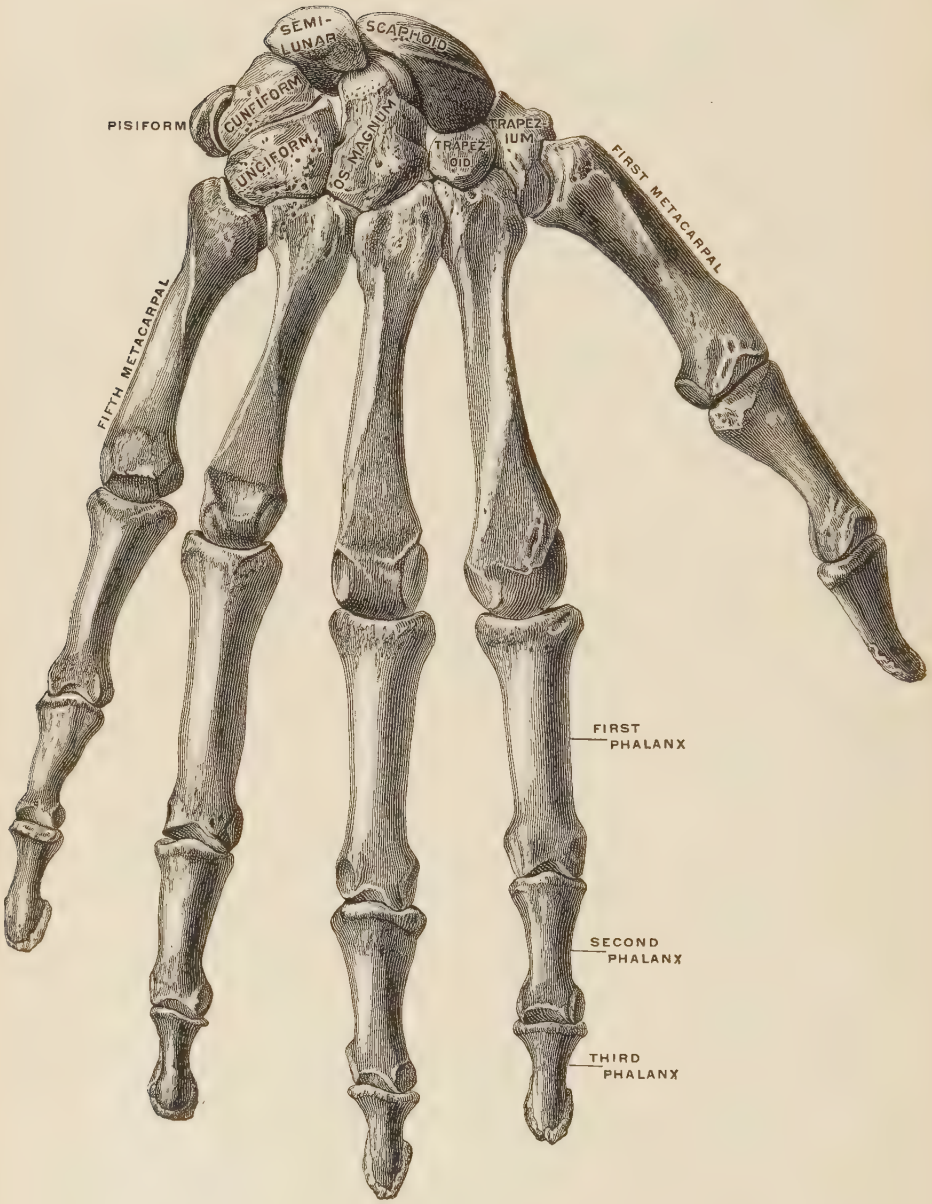


FIG. 74.—The bones of the right hand, dorsal aspect. (Spalteholz.)

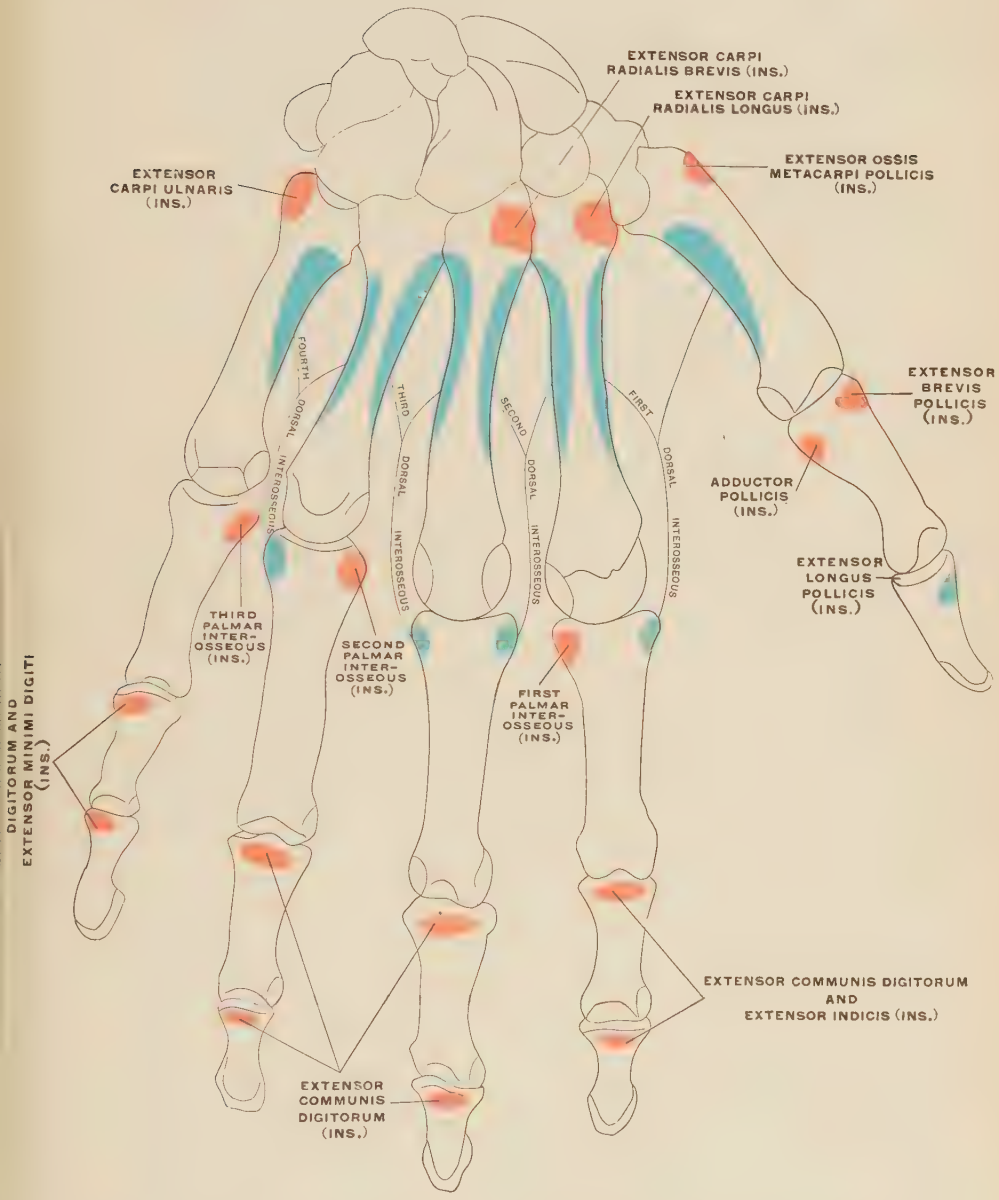

EXTENSOR CARPI RADIALIS BREVIS (INS.)
EXTENSOR CARPI RADIALIS LONGUS (INS.)
EXTENSOR OSSIS METACARPI POLLICIS (INS.)
EXTENSOR CARPI ULNARIS (INS.)
EXTENSOR BREVIS POLLICIS (INS.)
ADDUCTOR POLLICIS (INS.)
EXTENSOR LONGUS POLLICIS (INS.)
FOURTH DORSAL INTEROSSEUS
THIRD DORSAL INTEROSSEUS
SECOND DORSAL INTEROSSEUS
FIRST DORSAL INTEROSSEUS
THIRD PALMAR INTER-OSSEOUS (INS.)
SECOND PALMAR INTER-OSSEOUS (INS.)
FIRST PALMAR INTER-OSSEOUS (INS.)
DIGITORUM AND EXTENSOR MINIMI DIGITI (INS.)
EXTENSOR COMMUNIS DIGITORUM AND EXTENSOR INDICIS (INS.)
EXTENSOR COMMUNIS DIGITORUM (INS.)

FIG. 75.—Areas of muscular attachment on the dorsal surface of the bones of the hand. Where the areas of origin and insertion are both presented, they are in the same color. INS., insertion. (Gerrish.)

gives origin to the flexor profundus digitorum muscle in the upper three-fourths. The pronator quadratus muscle covers the lower fourth.

The posterior border is partly subcutaneous and gives origin to an aponeurosis common to the extensor carpi ulnaris, flexor carpi ulnaris and flexor profundus digitorum muscles. The internal surface in the upper part gives attachment to the flexor profundus digitorum muscle. The upper fourth of the dorsal surface shows a triangular area on which is inserted the anconeus muscle. Below this on the inner side is an attachment of the extensor carpi ulnaris muscle, while on the outer part of the surface, from above downward, are the extensor ossis metacarpi pollicis, extensor longus pollicis and extensor indicis muscles.

The lower extremity is small with a rounded head, the lower surface of which moves upon the triangular fibrocartilage of the wrist-joint. On the outer side is a facet that articulates with the sigmoid cavity of the radius. On the inner side, the bone is prolonged downward as the styloid process.

The *radius* takes but little part in the elbow-joint but is concerned in the wrist-joint. The upper extremity has a head, somewhat disk-shaped, with a cup-like cavity above, which articulates with the capitellum of the humerus. The side of the head articulates with the lesser sigmoid cavity of the ulna. Below the head is a rough prominence, the bicipital tuberosity, to which the tendon of the biceps muscle is attached.

The shaft of the radius is triangular and increases to a much greater size below. It presents three surfaces and three borders. To the internal border is attached the interosseous membrane. Passing from the bicipital tuberosity outward on the ventral surface is an oblique line which gives attachment to the flexor sublimis digitorum muscle. On the middle two-fourths of the anterior surface of the shaft is the flexor longus pollicis muscle. On the lower fourth the pronator quadratus muscle is attached. An oblique line on the dorsal surface with that on the front, bounds an external surface to which the supinator muscle is attached. Midway on the external surface is a rough impression for the pronator teres muscle. The dorsal surface in the middle third gives origin to the extensor ossis metacarpi pollicis and the extensor brevis pollicis muscles.

The lower extremity is much larger than the upper and is somewhat quadrilateral in form. Inferiorly is a cartilage covered surface with which two carpal bones, the scaphoid and semilunar, articulate. On the inner surface is the sigmoid cavity for the articulation with the head of the ulna.

The external surface is prolonged downward into the styloid process, to which is attached the brachio-radialis muscle.

When the hand is supine, the radius and ulna are parallel, but the radius crosses over the ulna, during pronation.

Carpal and Metacarpal Bones.—The *bones of the hand* consists of eight carpal, five metacarpal and fourteen phalanges. The carpal bones are arranged in two rows, named from the radial side inward, scaphoid, semilunar, cuneiform and pisiform in the upper row. Trapezium, trapezoid, os magnum and unciform in the lower row.

Articulating with the lower row are five metacarpal bones, numbered from the radial side inward, the first being that of the thumb. Two phalanges form the skeleton of the thumb, while each finger has three.

Many muscles are attached to the bones of the hand. See Figs. 72–75.

THE BONES OF THE LOWER EXTREMITY.

The skeleton of the lower extremity consists of the bones of the hip, thigh, leg and foot. A sesamoid bone, the patella, is included.

The Os Innominatum.—The hip-bone, or os innominatum is an irregularly shaped bone, having more resemblance to the blade of a ship's propeller than to anything else. It is expanded above and below but narrower in the middle, where the deep socket for its articulation with the femur is seen. This socket, the *acetabulum,* is cup-like and in youth shows the epiphyseal lines separating the three parts of which it is made. The cavity is covered with cartilage, except for a mass of fat at the bottom, and the rough impression for the ligamentum teres muscle. The lower part of the rim is incomplete, forming the cotyloid notch, which is bridged over by the transverse ligament, forming the cotyloid foramen.

The expanded upper part of the os innominatum forms the "false pelvis," a part of the wall of the abdomen, while the lower part forms the front and side walls of the "true pelvis."

The weight of the trunk, head and upper extremities is transmitted to the lower extremities through the hip-bones. The three parts of the bone are the ilium, ischium and os pubis, separate in early life but united in adult years. These will be considered in turn as more convenient to describe and more easily comprehended than the bone as a whole.

The Ilium.—The ilium presents a broad, flat and triangular appearance with a sinuously curved upper border, and narrowing to the lower part which occupies nearly two-fifths of the cavity of the acetabulum. The upper border or crest is subcutaneous, with two prominent processes at the ends, that in front being the *anterior-superior spine,* giving attachment to Poupart's ligament, while just below this the sartorius and tensor fascia lata muscles are attached. The crest ends posteriorly in the *posterior-superior spine,* which gives attachment to a ligament of the sacro-iliac joint.

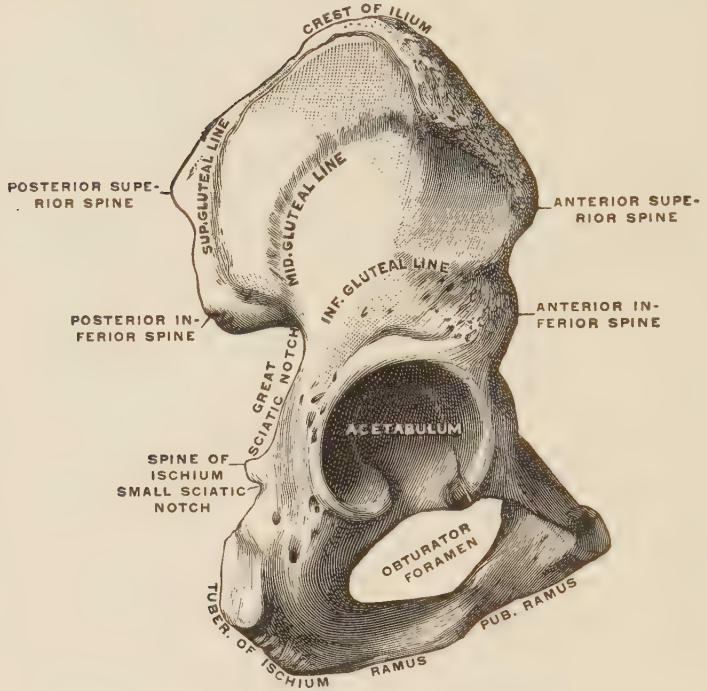


FIG. 76.—The right hip-bone, outer surface. (Testut.)

FIG. 77.—Areas of muscular attachment, outer surface of right hip-bone. (Testut.)

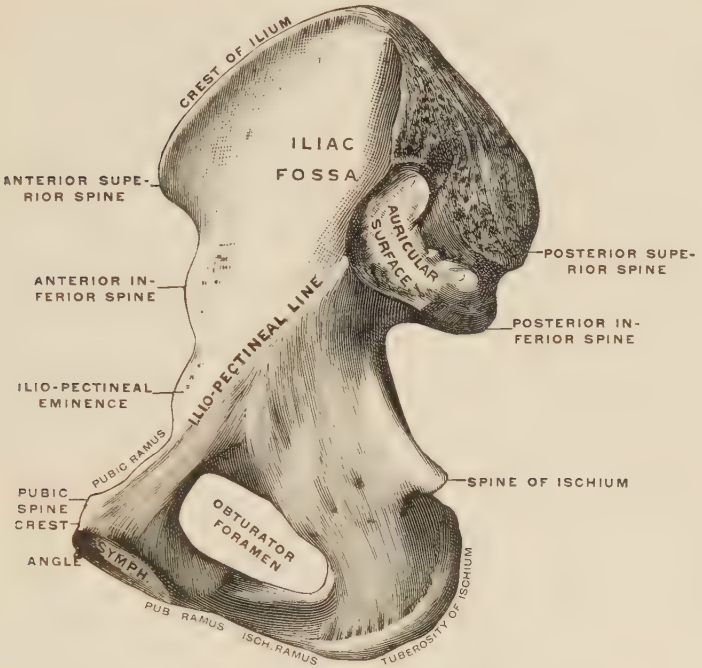


FIG. 78.—The right hip-bone, inner surface. (Testut.)

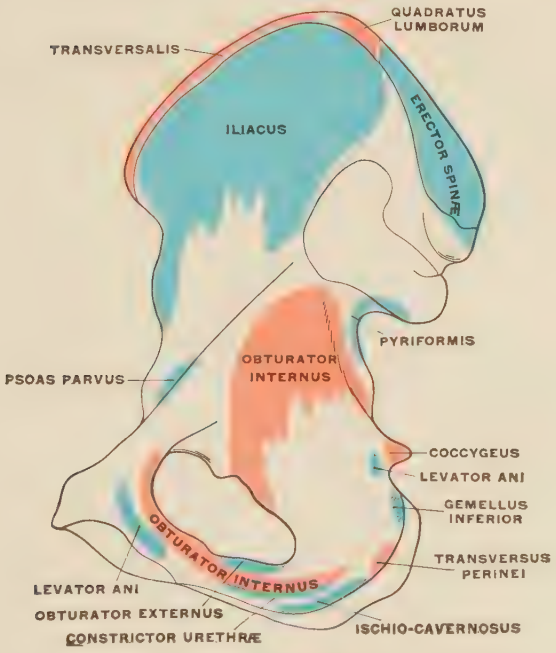


FIG. 79.—Areas of muscular attachment, inner surface of right hip-bone. (Testut.)

The crest is thick enough to be divided into three lips; inner, middle and outer. To the inner lip the transversalis muscle is attached on the anterior three-fourths, and the quadratus lumborum and erector spinæ muscles on the rest. To the middle lip the obliquus internus abdominis muscle, on the anterior two-thirds. To the anterior half of the outer lip, the obliquus externus abdominis, with the latissimus dorsi and the gluteus maximus muscles on the posterior half.

Below the anterior-superior spine is a notch, which ends in the *anterior-inferior spine,* to which is attached the rectus femoris muscle and the ilio-femoral band of the hip-joint. Below this spine is a broad shallow groove over which the tendon of the ilio-psoas muscle passes on its way to its insertion on the femur.

On the internal surface of the ilium is a fossa, the *iliac fossa,* giving attachment to the iliacus muscle. Behind this is an articular surface, corresponding to the same-shaped surface on the sacrum, the *auricular* surface, for articulation with each other. A rough surface above this provides for the posterior ligaments of the joint. The iliac fossa is bounded below by a slight ridge, called the ilio-pectinal line, which marks the top of the true pelvis. To this line is attached the pectineus muscle.

The posterior surface or dorsum of the ilium presents three lines, the superior, middle and inferior gluteal lines. Above the superior line is the gluteus maximus muscle; between the superior and middle lines is attached the gluteus medius muscle; between the middle and inferior lines is the gluteus minimus muscle.

Between the inferior line and the edge of the acetabulum is the attachment of the reflected tendon of the rectus femoris muscle. Below the posterior-inferior spine, on the ventral surface is the space occupied by the pyriformis.

The Ischium.—The ischium is the lower and posterior part of the hip-bone, and forms about two-fifths of the acetabulum. It presents a heavy thick tuberosity, a ramus, and a spine. The tuberosity is at the lowest part and supports the weight of the body when sitting in a correct position. It gives attachment to the semimembranosus, the semitendinosus, the biceps femoris, the adductor magnus, the gemellus inferior and the quadratus femoris muscles. From the tuberosity the ramus ascends to join the ramus of the os pubis, anteriorly. To it is attached the adductor magnus, the obturator externus and the obturator internus muscles. On the front wall of the true pelvis is a large foramen, the obturator or thyroid foramen, which in life is covered by the obturator membrane. From this and the edges around on the inner surface arises the obturator internus muscle. Above the tuberosity, posteriorly, is the spine, with a small notch (lesser sacro-sciatic) below and a large notch (greater sacro-sciatic) above. To the spine is attached the gemellus superior.

The Os Pubis.—The os pubis forms the anterior part of the true pelvis, and is composed of three parts, the body, the horizontal and the descending rami. The body is quadrilateral and in the lower front part gives attachment to the adductors longus, brevis and gracilis, and a part of the magnus muscles. On its upper border is the spine to which Poupart's ligament and the outer pillar of the external abdominal ring are attached. Along the upper border, internal to the spine is the crest, to which is attached the rectus abdominis, the pyramidalis muscles and the conjoined tendon of the obliquus internus and transversalis muscles. On the inner side of the body is a rough articular surface for its articulation with the fellow of the opposite side. The descending ramus joins the ramus of the ischium and gives attachment to the adductor magnus muscle. The horizontal ramus extends outward from the body to the ilium, and forms a fifth of the cavity of the acetabulum.

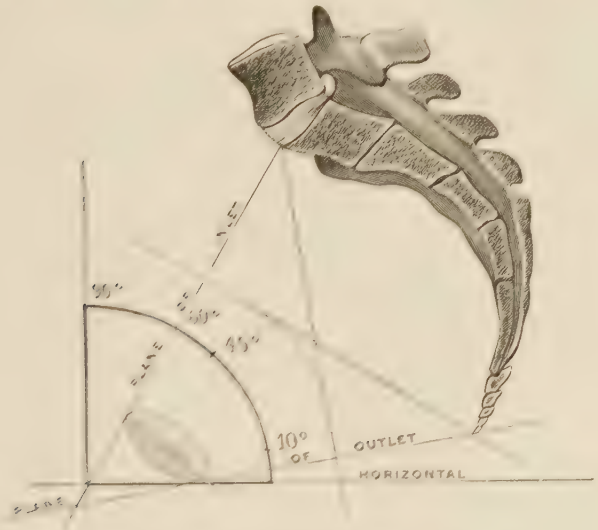


FIG. 80.—The planes of the pelvis. (Testut.)

The Pelvis.—The cavity of the pelvis is shallow in front and deeper behind. The opening at the top is called the inlet, while that below is the outlet. In the erect position of the body the pelvis is tilted so the plane of the inlet is at an angle of from 50 to 60 degrees with the horizontal, and that of the outlet at an angle of about 15 degrees. The weight of the body is transmitted from the sacro-iliac synchondroses to the acetabulum when in a standing position and to the tuberosities of the ischium when in a sitting position. To thus receive and transmit the weight there are very strong ridges of bone between these parts of the hip-bone, these ridges being strength-

ened and connected together anteriorly by counter arches which meet at the symphysis pubis. The expanded upper part of the pelvic girdle helps to support the abdominal viscera and furnishes attachment to many muscles forming the abdominal wall. The large surface, external and internal, gives opportunity for many muscles, with admirable leverage, to connect the trunk and lower extremities. The bones of the true pelvis contain and protect the pelvic viscera, and these are in intimate relation with those of the abdomen. The true pelvis in the two sexes differs in size and form. In the female the bones are smoother and lighter, as the muscles are usually exercised less vigorously. The cavity is broader, more capacious and less deep. About puberty, the female characteristics become marked, but prior to that the pelvis is undifferentiated,

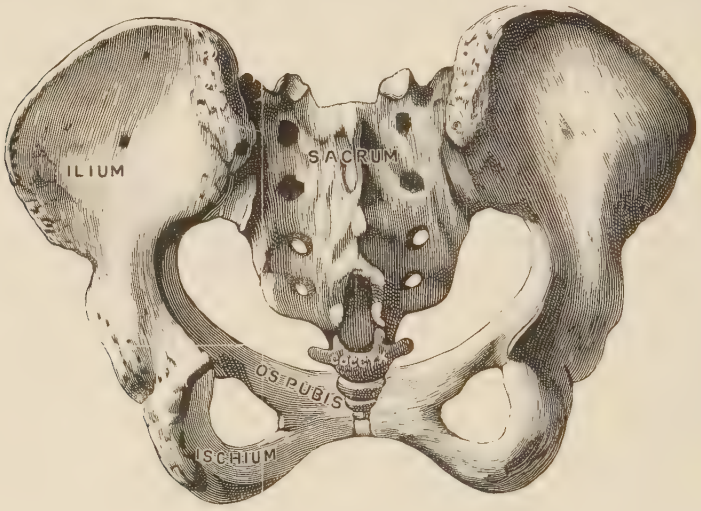


FIG. 81.—The female pelvis, rear view. (Testut.)

and the narrow and deep male type prevails. It is noticeable that the "athletic woman" is narrow in the hips and pelvis, retaining the characteristics of the pre-pubertal pelvis.

The Femur.—The femur, the longest bone of the body extends between the hip-bone and the tibia and articulates with both. It has a shaft and two extremities. The upper extremity presents a head, neck and two trochanters, great and small.

The head, which articulates with the acetabulum, is covered with cartilage in the recent state, and in shape is more than a hemisphere. Below and behind the center is a small depression for the ligamentum teres, which holds it to the acetabulum. The neck joins the head to the shaft, and is directed outward, downward and slightly backward, forming an angle of about 125 degrees with the

shaft. At the junction of the neck and shaft are two projections, a large one externally, the great trochanter; and a small one, the small trochanter, pyramidal in shape which presents from the inner and dorsal aspects.

The great trochanter is a heavy quadrilateral process continuous with the outer surface of the shaft, and whose upper surface is on a level with the highest part of the neck, locating the hip-joint. From the top of the great trochanter to the small one, run rough lines, that on the front, the anterior intertrochanteric, that on the back the posterior intertrochanteric line.

The anterior line limits the neck in front and gives attachment to the capsular ligament. This line is continued around the bone as the spiral line, and joins the *linea aspera*. The vastus internus muscle is attached to it. On the back of the trochanter is a rough vertical line, the gluteal ridge, to which the gluteus maximus muscle is attached. The quadratus femoris muscle is inserted near by. Externally on the trochanter are the attachments of the gluteus medius and minimus and the vastus externus muscles.

Just internal to the upper part of the trochanter is a deep fossa into which the finger fits snugly, and so named the *digital fossa*, on the floor of which is the insertion of the obturator externus muscles. Above and in front the gemelli, the obturator internus, and the pyriformis muscles are attached.

The small trochanter receives the tendon of the ilio-psoas muscle.

The shaft of the femur is nearly cylindrical, but with a flattened front and a prominent ridge behind, the linea aspera. It increases in size at the lower end. The front and sides of the shaft give attachment to the three vasti muscles, the internus, externus and intermedius.

The linea aspera formed by the joining of the spiral line and the gluteal ridge is thick and heavy in the middle third, and then divides into the internal and external condylar ridges, by which it continues to the condyles. The area enclosed by these ridges is the upper part of the popliteal space.

To the linea aspera are attached the adductors magnus, longus and brevis, the pectineus, the short head of the biceps femoris, the vasti externus and internus muscles.

The lower extremity of the femur is much expanded, and has two large condyles, internal and external. Behind they are separated by the intercondyloid notch, but in front the trochlear surface for the patella unites them. If the femur is held vertically, the internal condyle is apparently longer, but with the bone in position as in life, the lower edges are in line with each other and with the articular surface of the tibia. On the lateral surface of each condyle is a rough prominence, the tuberosity, which gives attachment to the ligaments of the knee-joint.

Fig. 82.—The right femur, front view. (Testut.)

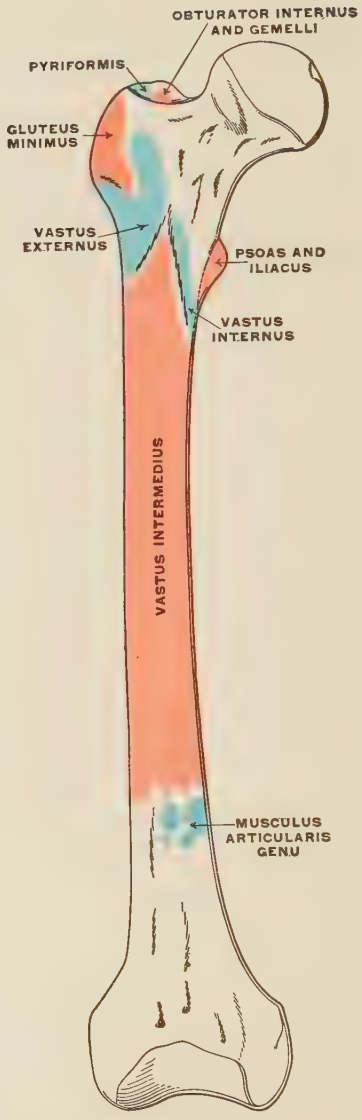


Fig. 83.—Areas of muscular attachment, ventral surface of right femur. (Gerrish.)

Above the posterior aspects of the condyles the two heads of the gastrocnemius muscle are attached; from the outer tuberosity the popliteus muscle and above that, the plantaris muscle.

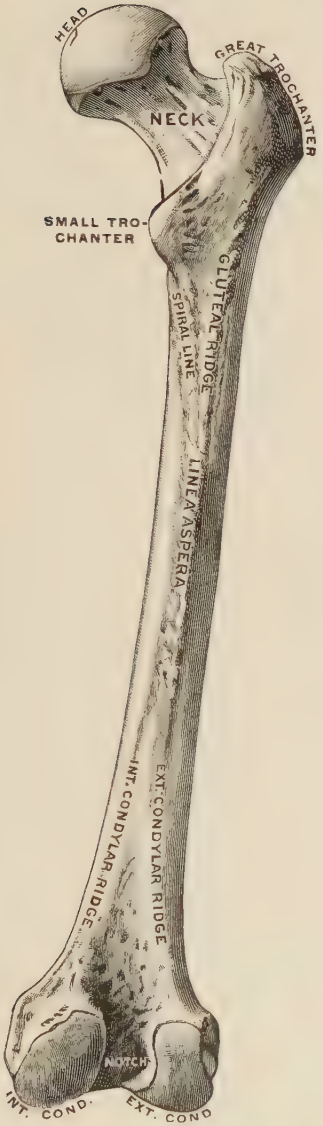


FIG. 84.—The right femur, rear view. (Testut.)

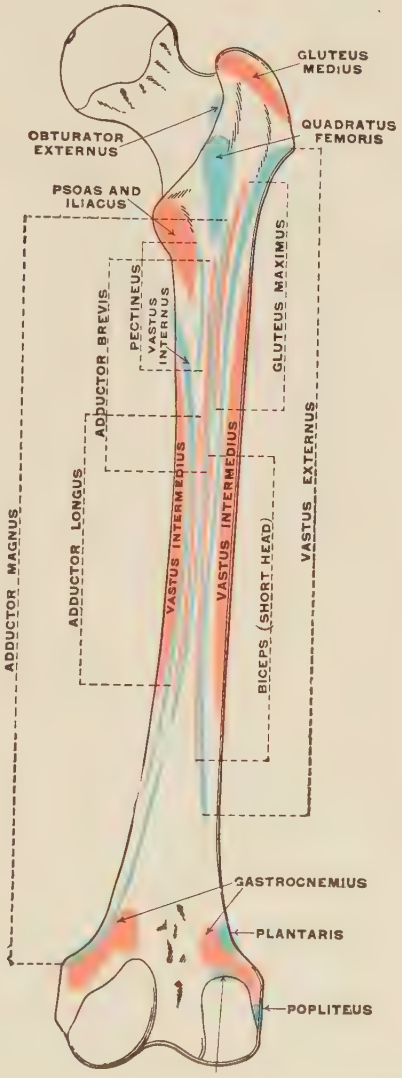


FIG. 85.—Areas of muscular attachment, dorsal aspect of right femur. (Gerrish.)

The Patella.—The patella on the front of the knee-joint is a small, flattish, sesamoid bone, with an articular surface dorsally and a rougher surface anteriorly. It articulates with the trochlear surface

of the femur and takes part in the complicated knee-joint. Anatomists differ as to whether it should be considered as contained within the tendon of the quadriceps extensor cruris muscle or as giving insertion to it.

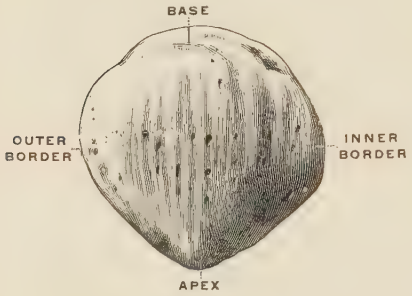


Fig. 86.—The right patella, ventral surface. (Testut.)

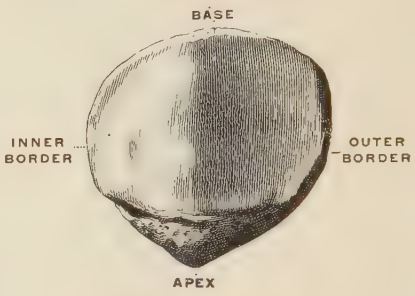


Fig. 87.—The right patella, dorsal surface. (Testut.)

The Tibia.—The tibia is the larger and heavier of the two bones of the leg, and presents a shaft and two extremities, the upper of which takes part in the knee-joint, and the lower in that of the ankle-joint. The upper extremity is thick and heavy with a tuberosity on each side. On the upper articular surface of these are depressions for the reception of the condyles of the femur. Projecting upward between these depressions is a spine, with a double peak, and behind this is a notch, the popliteal notch. With the area immediately below this, and that on the lower part of the femur, the diamond-shaped popliteal space is formed.

The lower part of the tuberosities in front is marked by a prominent elevation, the tubercle of the tibia, to which the tendon of the quadriceps extensor cruris muscle is attached. The body rests upon the tubercle in kneeling.

On the outer tuberosity, a little to the rear is an articular surface for the head of the fibula. On the inner tuberosity is seen a groove in which the tendon of the semimembranosus muscle is inserted.

The shaft of the tibia gradually tapers from the tuberosities downward, and is again expanded at the lower end. Just below the inner tuberosity on the lateral aspect of the shaft is the common attachment of the sartorius, gracilis and semitendinosus muscles.

The internal surface, below these muscular attachments is subcutaneous. The external surface presents a grooved area for the attachment of the tibialis anterior muscle on the upper two-thirds. On the posterior surface, from the articular facet for the head of the fibula, an oblique line passes downward and inward to nearly the middle of the shaft. This gives attachment to the soleus muscle and on the triangular surface above, to the popliteus muscle.

Below this line the space is divided between the tibialis posterior muscle on the outer side and the flexor longus digitorum muscle on the inner side.

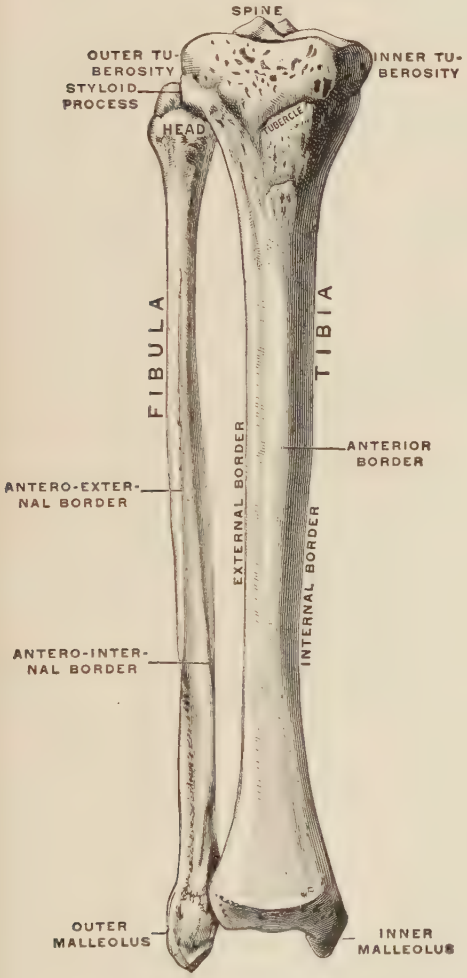


FIG. 88.—The right tibia and fibula in their normal relations, front view. (Modified from Testut.)

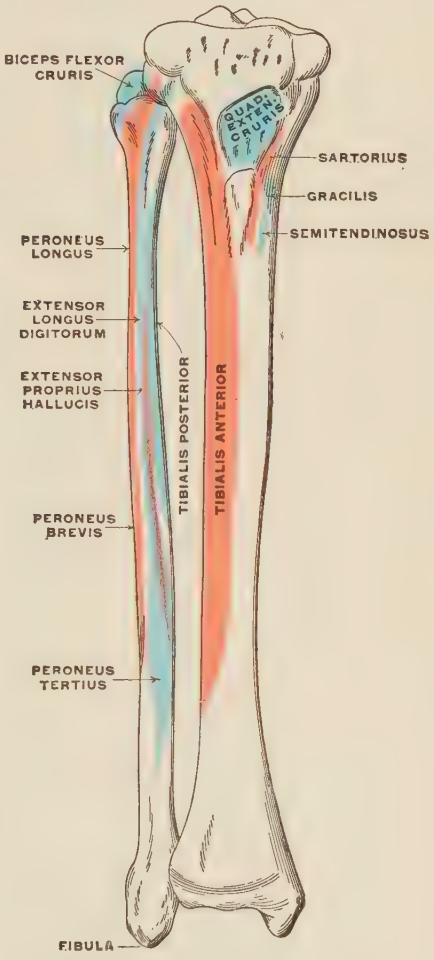


FIG. 89.—Areas of muscular attachment, anterior aspect of the tibia and fibula. (Gerrish.)

Of the borders, the external gives attachment to the interosseous membrane, and the anterior is noticeable for its sharp edge, "the shin," subcutaneous and serving as a sensitive outpost. The lower extremity of the tibia is expanded on the inner aspect into the *internal malleolus*, which enters into the formation of the ankle-

joint. On the opposite side is the surface for articulation with the fibula. On the under surface is a broad area for articulation with the astragalus. Grooves for the passage of tendons are seen on the back.

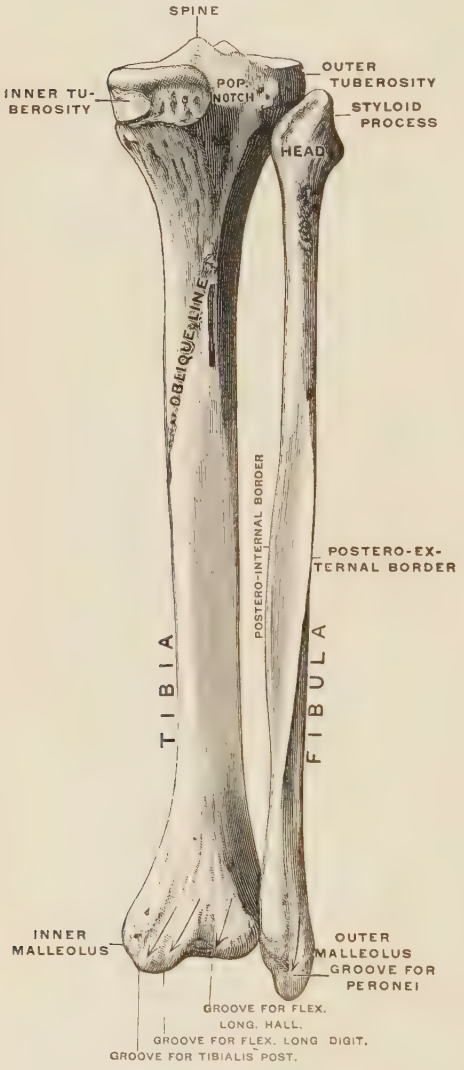


FIG. 90.—The right tibia and fibula in their normal relations, rear view. (Testut.)

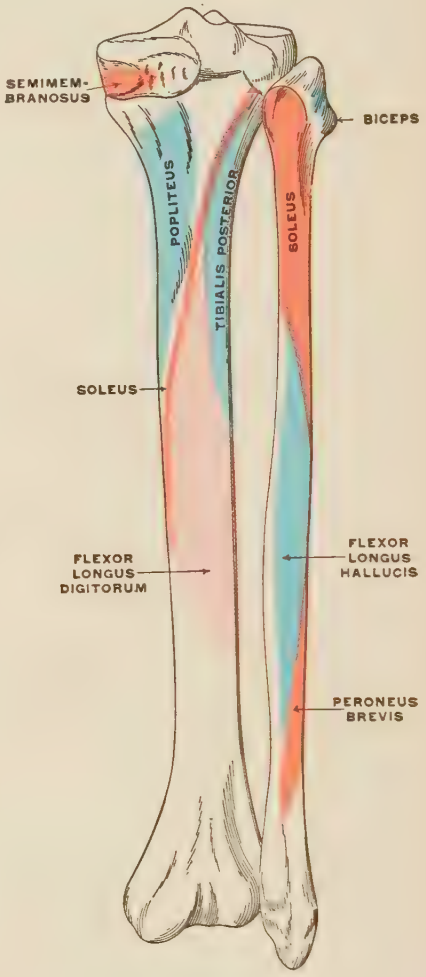


FIG. 91.—Areas of muscular attachment, posterior aspect of the tibia and fibula. (Gerrish.)

The Fibula.—The fibula or the outer bone of the leg is very slender, with the surfaces changing in direction so frequently it is very

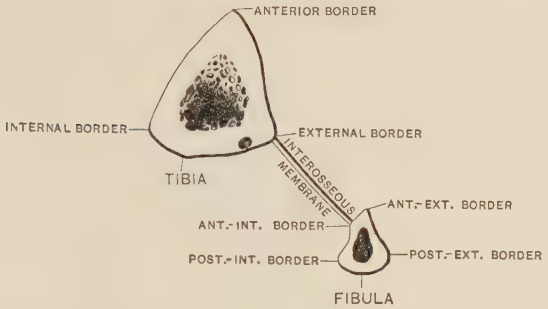


FIG. 92.—Horizontal section of the bones of the leg at the junction of the upper and middle thirds, showing their borders and surfaces and the relations of the interosseous membrane. (Testut.)

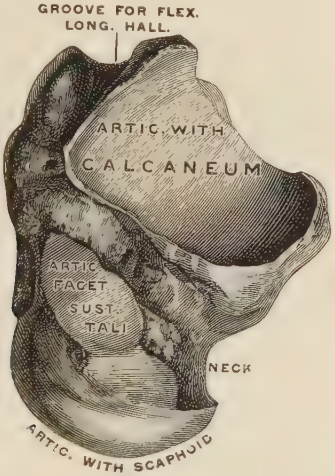


FIG. 93.—Right astragalus, under surface. (Spalteholz.)

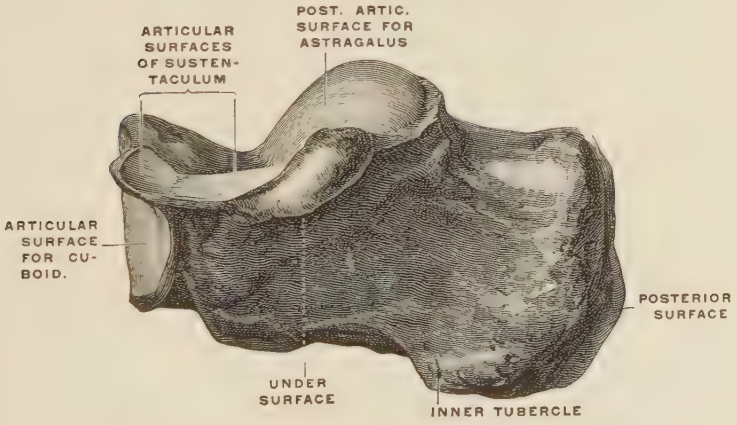


FIG. 94.—Right calcaneum, internal surface. (Spalteholz.)

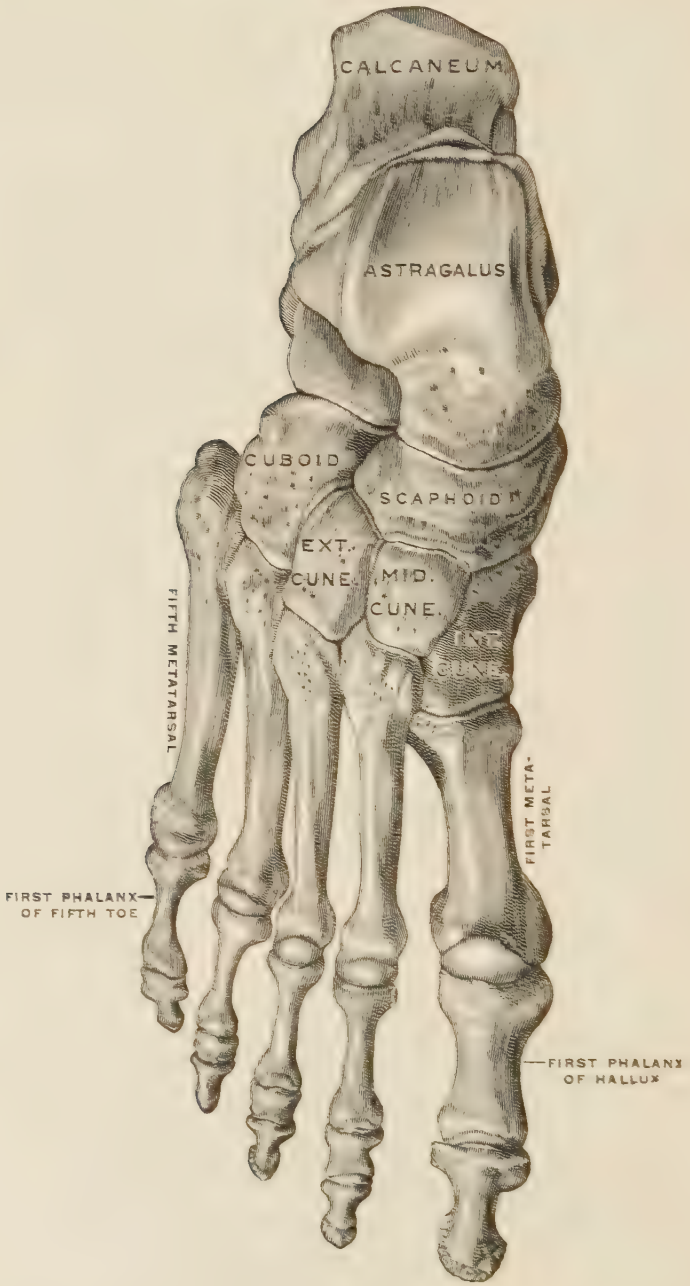


FIG. 95.—The bones of the right foot, viewed from above. (Albinus.)

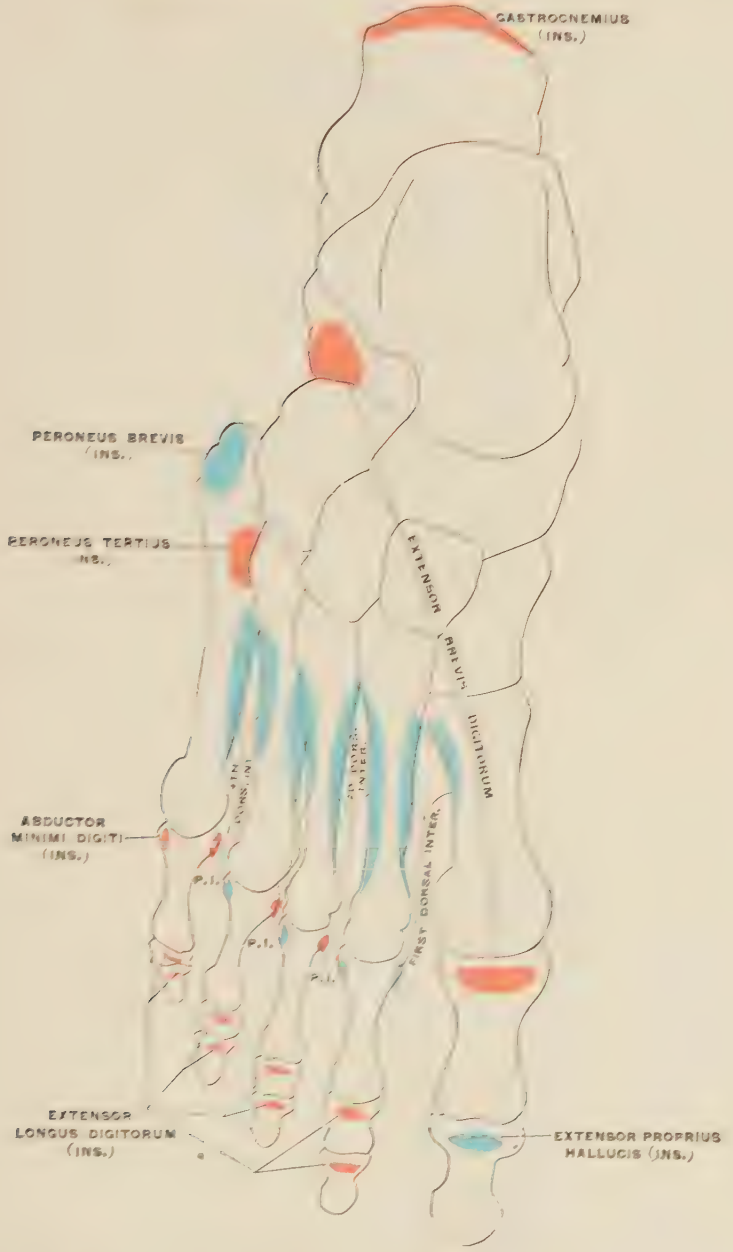


FIG. 36.—Areas of muscular attachment on the dorsal surface of the bones of the foot. Where the areas of origin and insertion are both presented they are in the same color. The third dorsal interosseous is not labeled. P.I., plantar interosseous insertion; INS., insertion. (Gerrish.)

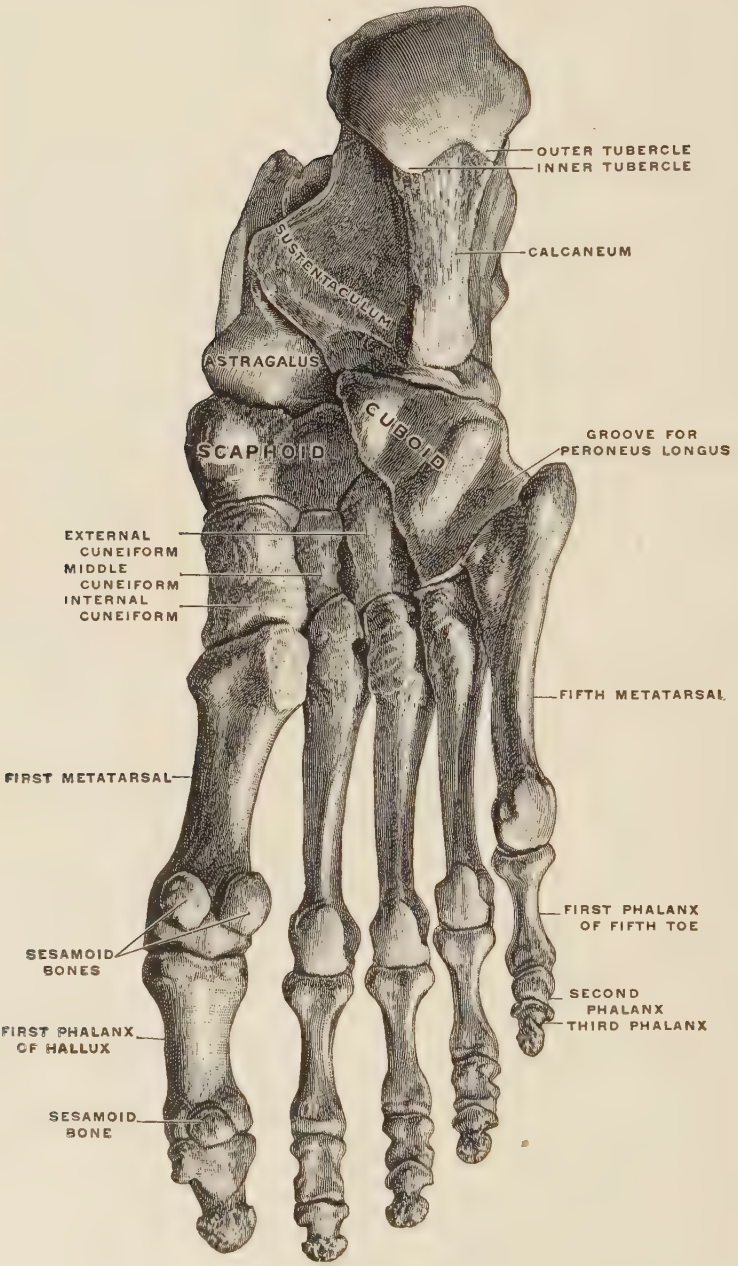


Fig. 97.—The bones of the right foot, viewed from below. (Spalteholz.)

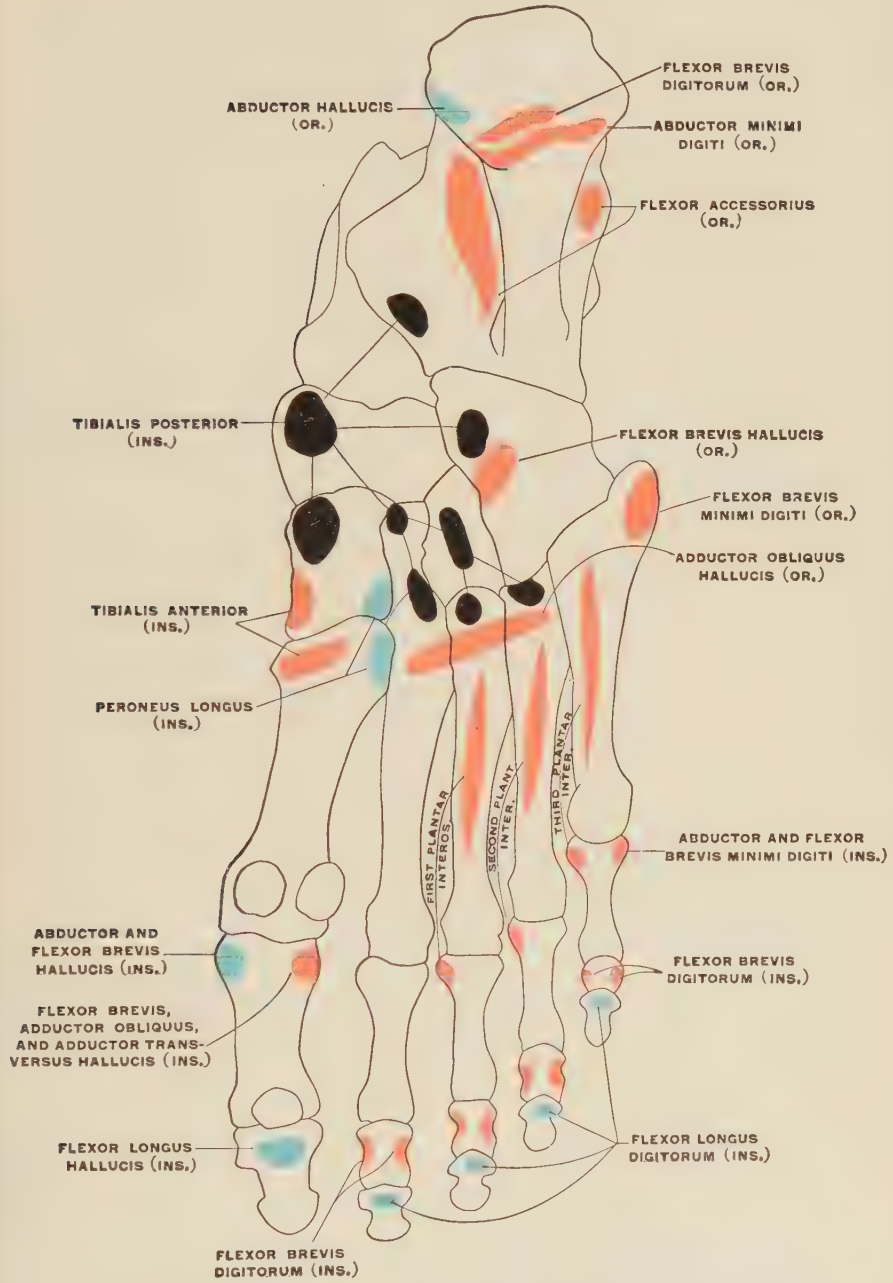

FLEXOR BREVIS DIGITORUM (OR.)
ABDUCTOR HALLUCIS (OR.)
ABDUCTOR MINIMI DIGITI (OR.)
FLEXOR ACCESSORIUS (OR.)
TIBIALIS POSTERIOR (INS.)
FLEXOR BREVIS HALLUCIS (OR.)
FLEXOR BREVIS MINIMI DIGITI (OR.)
ADDUCTOR OBLIQUUS HALLUCIS (OR.)
TIBIALIS ANTERIOR (INS.)
PERONEUS LONGUS (INS.)
FIRST PLANTAR INTEROS
SECOND PLANT INTER.
THIRD PLANTAR INTER.
ABDUCTOR AND FLEXOR BREVIS MINIMI DIGITI (INS.)
ABDUCTOR AND FLEXOR BREVIS HALLUCIS (INS.)
FLEXOR BREVIS DIGITORUM (INS.)
FLEXOR BREVIS, ADDUCTOR OBLIQUUS, AND ADDUCTOR TRANSVERSUS HALLUCIS (INS.)
FLEXOR LONGUS HALLUCIS (INS.)
FLEXOR LONGUS DIGITORUM (INS.)
FLEXOR BREVIS DIGITORUM (INS.)

FIG. 98.—Areas of muscular attachment on the plantar surface of the bones of the foot. Where the areas of origin and insertion are both presented they are in the same color. OR., origin; INS., insertion. The insertion of the second and third tendons of the flexor brevis digitorum are not labeled. (Gerrish.)

difficult to distinguish and describe borders or surfaces. The upper extremity or head has a conical process above, the *styloid process,* to which the tendon of the biceps femoris muscle is attached.

A facet provides for the articulation with the tibia. The shaft gives attachment to the anterior group of muscles that flex the foot, namely, extensor longus digitorum, proprius hallucis and peroneus tertius; the external or foot pronator group, peroneus longus and brevis; the posterior or foot extensor group, flexor longus hallucis and soleus; and the supinator muscle, tibialis posterior. The lower extremity presents the external malleolus, a process that extends downward beyond that on the inner side, to take part in the ankle-joint. A facet on the inner side articulates with the tibia and another, somewhat to the front, with the astragalus.

The Bones of the Foot.—The bones of the foot have an arrangement similar to that in the hand, but with certain essential differences due to the differences in function. While the hand is a prehensile organ, the foot is an organ for support and locomotion.

Seven tarsal, five metatarsal and fourteen phalanges make up the total. The description of the tarsal bones follows.

The Astragalus.—The astragalus unites with the tibia and fibula to form the ankle-joint. It is joined to the calcaneum behind and to the scaphoid in front. The weight of the body is transmitted to the astragalus through the tibia, so the bone is of necessity strong and heavily built.

The Calcaneum.—The calcaneum or heel bone is the largest of the tarsal bones and transmits the weight of the body to the ground. The hind part of the bone is placed lower than the front, and on the posterior surface gives attachment to the tendo Achillis, the combined tendon of the gastrocnemius, soleus and plantaris muscles. Jutting out from the inner side is a shelf-like process the sustentaculum tali, on which the astragalus rests in its articulation with the calcaneum. On the anterior aspect is a facet for articulation with the cuboid.

The Cuboid.—The cuboid is in front of the calcaneum and on the outer side of the foot. It articulates with the fourth and fifth metatarsals, as well as with the calcaneum. On the under surface is a deep groove through which passes the tendon of the peroneus longus muscle.

The Scaphoid.—The scaphoid is placed on the inner side in front of the astragalus with which it articulates, as well as with the cuboid, the internal, middle and external cuneiforms. It has a tubercle on the inner surface which serves to locate the medio-tarsal-joint and gives attachment to the tibialis posterior muscle.

The Cuneiform Bones.—Three cuneiform bones in front of the scaphoid are wedge-shaped and articulate with each other, with the scaphoid, the cuboid and all the metatarsals except the fifth.

The Metatarsal Bones.—The five metatarsal bones articulate with the front row of the tarsus and with the first phalanx of the corresponding toes. That of the great toe is much heavier than the others, and the fifth or the metatarsal of the little toe is the longest, with a prominent tubercle at its upper end.

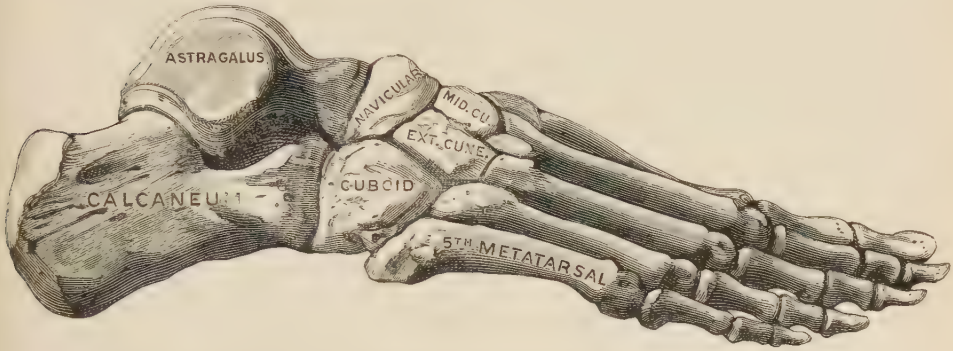


FIG. 99.—The bones of the right foot, viewed from the outer side. (Testut.)

The Phalanges.—The phalanges, two for the great toe and three for all the others are similar to those of the hand, but much shorter, especially the terminal or ungual phalanges.

Many muscles find attachment to the bones of the foot. See Figs. 96–98.

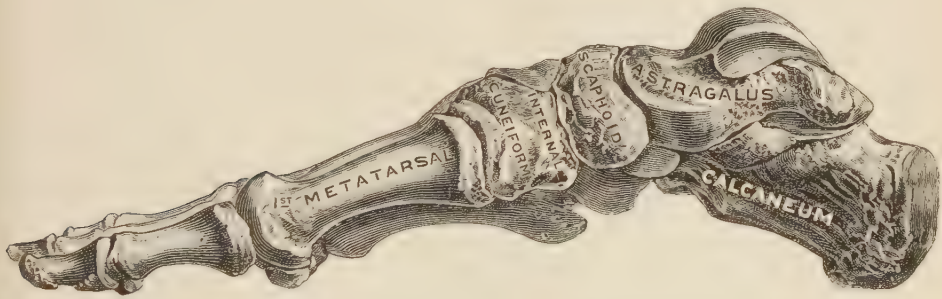


FIG. 100.—The bones of the right foot, viewed from the inner side. (Spalteholz.)

The Foot as a Whole.—The bones of the foot form two arches, one longitudinal, the other transverse. When the two feet are placed side by side, the structure is a dome, which is architecturally the strongest form of support possible for the weight of the body.

The bones concerned in the long arch are the astragalus as the keystone, the calcaneum as the posterior division, the scaphoid, three cuneiform, and first three metatarsals as the anterior division.

The outer part of the foot, the cuboid and two outer metatarsals serve as a buttress to the arch.

The transverse arch has its inner pier at the internal cuneiform and the first metatarsal; the outer pier at the cuboid and the fifth metatarsal.

This arrangement of the bones provides protection for the muscles and nerves in the sole of the foot, adds to the spring in walking and lessens jar in falling upon the feet as well as increasing their beauty.

While the weight of the body ordinarily rests upon the heel, it should fall about under the scaphoid. In normal barefoot walking the front of the foot touches the ground before the heel does, but this is not the case when shoes with heels are worn.

QUESTIONS.

How many bones to form the *cranium?* Why should there be that many?

Name the parts of a typical *vertebra.*

How are the *cervical* vertebræ distinguished?

How are the *thoracic* vertebræ distinguished?

Describe a typical *rib.*

Name the parts of the *scapula.*

Distinguish the right *humerus,* and place it so it will correspond with its position in the body.

What are the markings on the *radius?*

How many *carpal* bones are there? Why should there be so many bones in a hand?

What and where is the *patella?*

How is the *femur* directed when articulated?

Name the principal points of interest on the *ilium.*

What is the "*linea aspera?*"

What is the *tubercle of the tibia,* and what is attached thereto?

What is the "*arch of the foot?*"

Find on yourself the principal bony landmarks, such as the olecranon process, the acromion, etc.

CHAPTER IV.

THE ARTICULATIONS.

The bones of the skeleton are held together in place by articulations or joints, which have certain common characteristics. In a typical joint, the expanded ends of two bones are covered with hyaline cartilage in a thin layer, with greater thickness where the pressure is greater. This cartilage makes for smoothness, lack of friction, and elasticity. There may be rings or plates of fibrocartilage around or between bones to deepen sockets or to secure better adaptation of surfaces or increase the buffer action.

A continuous sheath of white fibrous tissue covers in the joint, holding the bones together, with accessory bands where the strain is greater. The white fibrous tissue while flexible is inextensible, so there is no danger of the bones separating farther than for the normal range of movement.

Inside the fibrous sheath is a lining of epithelial tissue, which secretes a glairy material similar in appearance to the white of an egg, called *synovia*. This is to lubricate the joint.

In addition, small sacs, or bursæ, are frequently present to provide lubrication to structures around the joint (periarticular).

Classes of Joints.—Such a joint as that described above allows a more or less free range of movement, and is classed as *diarthrodial*. Several subdivisions of this class are made, to be described later.

Some joints are made by two bones in contact without the covering of cartilage, as in the sutures of the skull, where a layer of fibrous material holds them together.

Or, there may be a socket of bone, into which a cone of cartilage fits, and is held by the perichondrium and the periosteum, as in the articulation of the ribs with their cartilages. Such joints permit no motion and are called *synarthrodial*.

Another class have a plate of fibrocartilage between the bones which is firmly attached to both, as in the *symphysis pubis*, and in the articulations between the bodies of the vertebræ. These joints have a small amount of motion and are called *amphiarthrodial*.

The *diarthrodial joints* are divided into several classes according to the kind of motion permitted. This is dependent upon the shape of the articulating surfaces, but the ligaments connecting the bones and the surrounding muscles limit the motion.

When a movement takes place about a transverse axis, giving a

change in the extent of the angle between the bones, it is called *flexion* if the angle is reduced, and *extension* if the angle is increased. If an angular movement toward the middle line of the body, the middle of the second finger or the second toe occurs, it is called *adduction*. If the movement is away from these centers, the movement is *abduction*.

A combination of the above four movements in one continuous movement is *circumduction*, with the figure of a cone described in space, the apex at the joint and the base of the cone at the further extremity. This should not be confounded with rotation.

Rotation is the movement of a bone around a longitudinal axis, in which the figure described in space is a cylinder.

Gliding is a sliding of surfaces upon each other without any angular or rotary movement.

Classes of Diarthrodia.—*Arthrodia* or gliding joints allow a limited gliding between two nearly flat surfaces, as those of the articular processes of the vertebræ.

Ginglymus or hinge joints allow movements of flexion and extension about a transverse axis, as in the elbow- and knee-joints.

Condyloid joints allow abduction, adduction, flexion, extension and circumduction, but *not rotation*, as the surfaces of bone forming the joint are oblong and spheroidal in form. The metacarpophalangeal joints illustrate this kind of joint.

Reciprocal Reception.—A modification of condyloid joints, called either "saddle joints" or those of reciprocal reception have the surfaces reciprocally saddle-shaped, as in the carpo-metacarpal joint of the thumb. They allow all movements except rotation.

Ball-and-socket joints, such as those at the hip and shoulder consist of a more or less spherical head received into a cup-shaped cavity. They allow free movement in every direction.

Pivot joints, those between a pivot and encircling ring, as in the articulation between the axis and atlas, and that between the upper parts of the radius and ulna, allow the movement of rotation only. In describing the articulations, those not of particular interest to the student of hygiene will be given but brief consideration.

THE ARTICULATIONS OF THE VERTEBRAL COLUMN.

These include the joints between the bodies of the vertebræ, the articular processes, the laminæ, the spinous processes and the transverse processes.

The *bodies* of the vertebræ are joined together by disks of fibrocartilage, which correspond in shape with the bodies. These disks are tough, elastic and compressible, varying in thickness in different regions of the spine. In the center of the disk is a spherical mass of pulpy material, which is compressed by the layers of fibrocartilage,

so it rebounds when the mass is cut across, and seems like a small ball or pivot. Around this mass, the vertebræ move in every direction. The thickness of these disks varies, being thinnest in the cervical, and thickest in the lumbar region of the spine.

Passing down the front of the bodies and intervertebral disks is the anterior common ligament, beginning at the under surface of the occiput, as a narrow band, and widening as it descends until it reaches the sacrum. This ligament connects the front of the bodies of the vertebræ and limits the movement of extension.

The posterior common ligament passes along the posterior surfaces of the bodies and disks, from the occiput to the coccyx, being broader above and narrower below. It connects the backs of the bodies, helps to form the lining of the vertebral canal, and limits flexion of the spine.

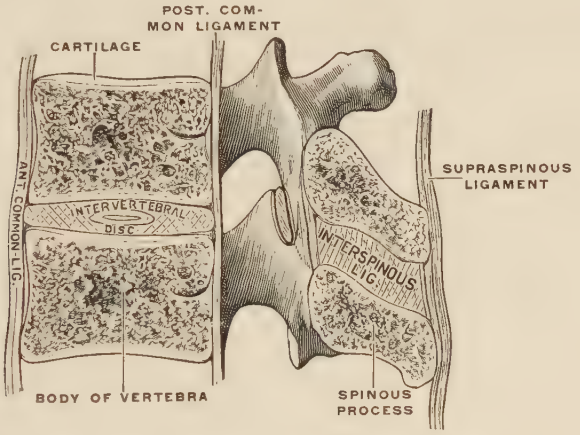


FIG. 101.—Two lumbar vertebræ in sagittal section. (Testut.)

These intervertebral articulations are amphiarthrodial joints, allowing slight movement in every direction with the fibrocartilages compressed when the rest of the spinal articulations are in movement.

The joints between the articular processes are gliding joints, having capsular ligaments lined with synovial membrane. These ligaments are loosest in the cervical region and tightest in the thoracic.

Connecting the laminæ are ligaments that are unusual in that they contain elastic fibrous tissue. These are the *ligamenta subflava*, and besides causing the return of the surfaces to their normal position after each movement, they prevent the capsular ligaments from being pinched between the articular surfaces during such movement of the spine. The tips of the spinous processes are connected by bands of fibers, called the supraspinous ligaments. In the cervical region, these are accentuated as the ligamentum nuchæ,

or nape ligament. In quadrupeds this is very strong, as it supports the head, but it is much less marked in man, and has some elastic fibers. It gives attachment to several muscles. Ligaments pass from the under surface of one spine to the upper border of the spine below, and between the transverse processes.

The spinal column is the axis of the skeleton, and every movement of the body influences its position, and the pull of the muscles acting upon it. Further, it must resist jar and provide strength with mobility. The motion between any two vertebræ is slight, but the sum of the movements of the twenty-six vertebræ amounts

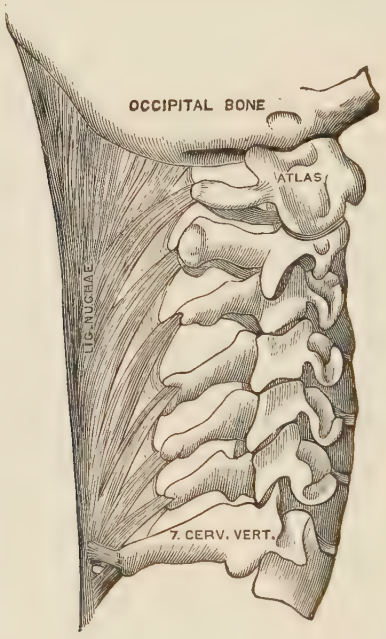


Fig. 102.—The ligamentum nuchæ, seen from the right side. (Henle.)

to a relatively large range. Around the pulpy ball in the center of the intervertebral fibrocartilage, the movement is in every direction, as of a ball-and-socket joint, but limited by the articular processes and the ligaments. Noting the direction in which the articular processes face, and remembering that gliding is their only possible movement, it is seen that in the cervical region the obliquity of the surfaces would allow some movement in practically all directions. In the dorsal region, side bending would be more possible and in the lumbar spine the movements of flexion and extension would take place most readily.

The overlapping spines in the thoracic region limit extension

while the attached ribs prevent much movement laterally. The thick intervertebral disks in the lumbar region provide for fairly free movement, and the small bodies in the cervical region allow a similar freedom there.

The spine is a flexible structure, already curved in two directions in the antero-posterior plane, and as Lovett has so well pointed out it must be considered as a flexible curved rod, and cannot be bent laterally without accompanying torsion.

ARTICULATIONS IN THE UPPER CERVICAL REGION.

The condyles of the occiput articulate with the facets on the upper surface of the *atlas*, forming a condylar joint. Flexion, extension and side bending, but not rotation is possible. The articulation between the odontoid process of the axis, and the atlas provides for free rotation, and the movements of the head on the atlas and of the atlas on the axis are usually closely associated and merged, amounting to a very free range, as though it were a ball-and-socket joint.

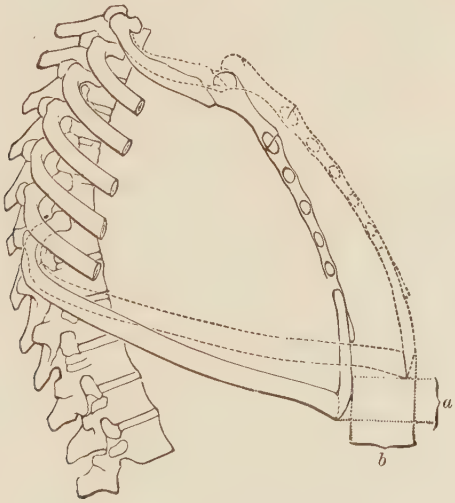


FIG. 103.—Diagram of the displacement of the ribs and sternum in inspiration: *a*, indicates the degree of upward movement; *b*, that of forward movement. (Testut.)

ARTICULATIONS OF THE THORAX.

The anterior ends of the first seven ribs articulate with the facets on the sternum, and allow a slight hinge movement on the sagittal and obliquely vertical axis. The cartilages of the next three ribs are joined to that of the seventh and thus indirectly to the sternum.

Posteriorly, the heads of the ribs articulate with either the body of the corresponding thoracic vertebra, or with the bodies of two adjoining vertebræ and the intervertebral fibrocartilage. The tubercles of the ribs articulate with the facets on the transverse processes of the vertebræ. Capsular ligaments hold the bones together.

The movement at these joints is mostly rotation around an oblique axis upward or downward. The ribs are inclined obliquely downward, and during the movement of inspiration, the inclination is lessened as the sternal ends of the ribs move forward-upward. This increases the sagittal diameter of the thorax. At the same time, the lateral diameter is increased by the lessening of the angle with the costal cartilages, in front, and by the elevation of the lateral part of the rib and the eversion of the lower border, behind. The upper ribs, first and second, being flatter and with less obliquity are raised in inspiration, so increasing the vertical diameter of the thorax. During expiration, the reverse action takes place by the relaxation of the muscles.

THE ARTICULATIONS OF THE UPPER EXTREMITY.

The upper extremity is attached to the main skeleton at only one place, the articulation between the clavicle and the sternum.

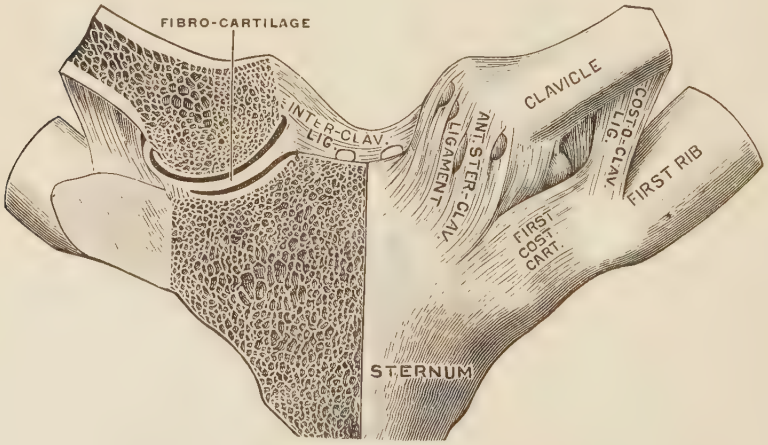


FIG. 104.—Sterno-costo-clavicular articulation, front view. The left half is seen in coronal section. (Testut.)

The Sterno-clavicular Articulation.—In the sterno-clavicular articulation the two surfaces of bone, the facet on the manubrium and the end of the clavicle do not fit accurately together, so there is a plate of fibro-cartilage interposed, with synovial cavities on each

side of it. The surfaces glide upon each other as a rounded head in a shallow socket. This, while giving freedom, makes for easy displacement. To prevent upward displacement, a strong band of fibers, the *interclavicular* ligament, passes from the end of one clavicle to that of the other and dips down to the upper border of the sternum. Anterior and posterior sterno-clavicular bands guard the joint front and back, and additional fibers complete a capsule.

An accessory band of fibers, the *costo-clavicular* or *rhomboid* ligament, joins the lower surface of the clavicle to the front of the first rib. This aids in preventing upward displacement, as well as that in the backward direction.

The student should place one finger on the articulation and note the movements of the clavicle when raising and lowering and carrying the arm forward and backward.

The clavicle with the scapula moves up and down, backward and forward and in circumduction. On raising the arm a slight rotation occurs.

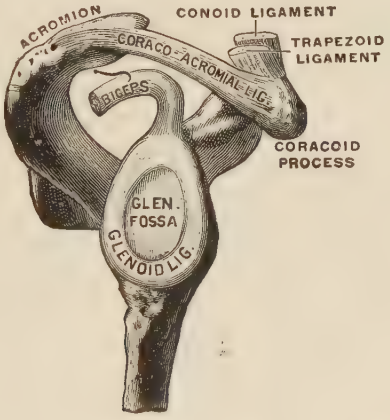


FIG. 105.—Glenoid fossa of right side. (Testut.)

The Scapulo-clavicular Articulation.—The scapula is joined to the clavicle by a gliding joint between the acromial end of the clavicle and the acromion of the scapula. The capsular ligament surrounding it, allows only a small amount of movement.

A much stronger union is made between the coracoid process of the scapula and the under surface of the clavicle. From the root of the coracoid process, strong bands of fibers pass to the *conoid* tubercle of the clavicle. This is the conoid ligament by which the scapula is said to hang from the clavicle. From the upper surface of the coracoid process the *trapezoid* ligament extends to the trapezoid ridge of the clavicle. Movements of the acromio-clavicular joint are usually combined with those of the sterno-clavicular joint. The combination of turning the glenoid fossa upward or downward,

with the elevation or depression of the clavicle results in what is known as the rotation of the scapula. When the arm is raised, this rotation turns the glenoid fossa more upward and outward and carries the lower angle outward. The reverse occurs in lowering the arm.

The scapula and clavicle move independently of the arm with an upward and forward movement, and a downward and backward movement. In these, the lower angle of the scapula does not move outward toward the axilla as in the movements associated with arm raising or lowering.

An additional union between the clavicle and scapula is made by the coraco-acromial ligament, passing between the coracoid process and the acromion, and forming an arch over the shoulder joint. This protects the joint and holds off the deltoid muscle.

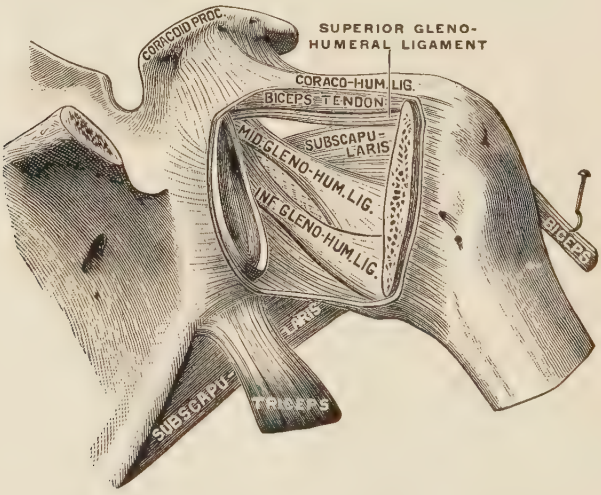


Fig. 106.—Shoulder-joint, rear view. The hind part of the capsular ligament and most of the head of the humerus have been removed. (Testut.)

The Shoulder-joint.—The parts concerned are the rounded head of the humerus and the glenoid fossa of the scapula. Both surfaces are covered with cartilage, and around the edge of the fossa to deepen it is a rim of fibro-cartilage, the glenoid ligament, which is triangular on cross-section. From the circumference of the fossa the capsular ligament extends to the anatomical neck of the humerus. This capsule is longer than the actual distance requires but allows great mobility in the joint. The synovial membrane lines the capsule and extends down into the bicipital canal. The capsular ligament does not hold the bones together, but as a vacuum exists within the capsule, atmospheric pressure does. Various tendons

serve to help prevent dislocation. That of the biceps muscle goes within the capsule, and to the upper border of the fossa, guarding the joint above. This is noticeable when the arm is in abduction, and the latissimus dorsi and pectoralis major muscles are pulling downward, as in hanging by the hands.

Tendons of supraspinatus, infraspinatus and teres minor muscles are above and posterior; that of the triceps muscle below, the subscapularis muscle in front. Between these two latter, is an unprotected space, that allows the head of the humerus to be dislocated under violent strain.

The inner surface of the front of the capsule is further strengthened by three bands, *gleno-humeral*, passing from the edge of the fossa to the greater tuberosity of the humerus.

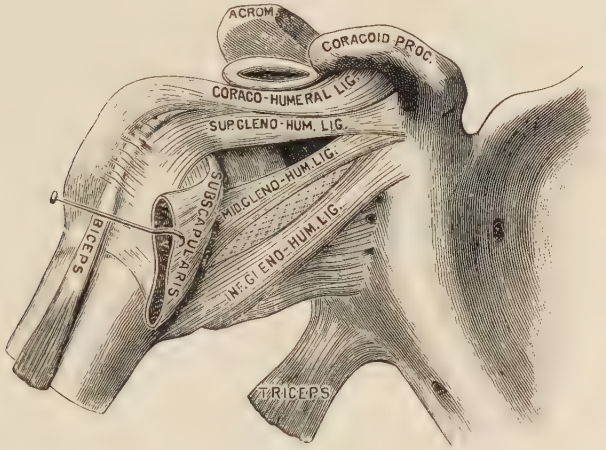


FIG. 107.—Shoulder-joint, front view. (Testut.)

Strong bands pass from the coracoid process of the scapula to the anatomical neck of the humerus, in close association with the capsule.

The shoulder-joint is a ball-and-socket joint, allowing movement in all directions, flexion, extension, rotation, abduction, adduction and circumduction. Flexion and extension, abduction and adduction are possible through 90 degrees. In abduction, the head of the humerus is prevented from going further by the greater tuberosity striking against the acromion process and by the coraco-acromial ligament.

Before the arm has gone far in these movements, the glenoid fossa begins to turn, so complete extension or abduction takes place by the combination of rotation of the scapula, and the movement at the shoulder-joint.

Inward and outward rotation occurs around an axis from the center of the head to the inner condyle of the humerus, with a range of about 90 degrees. The subacromial bursa between the capsule and the deltoid muscle is important to remember.

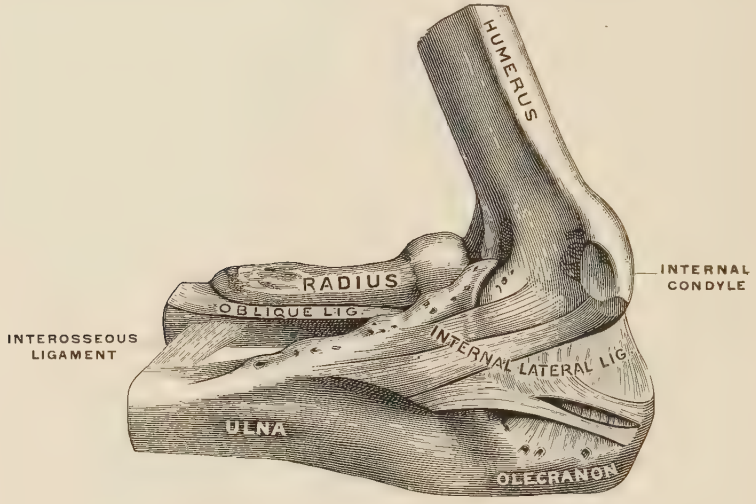


Fig. 108.—Elbow-joint, mesial view. (Poirier.)

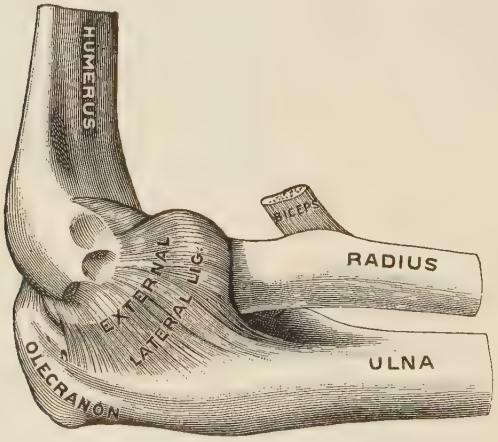


Fig. 109.—Elbow-joint, outer side. (Testut.)

The Elbow-joint.—This is formed by the trochlear surface of the humerus and the greater sigmoid cavity of the ulna. Both surfaces are covered with cartilage, and a capsule surrounds the joint, with bands of fibers accentuating the internal, external, anterior and posterior aspects. Of these, the internal lateral bands are the strongest. The anterior fibers are attached to the brachialis muscle,

which contracts in flexion of the elbow, and draws the capsule out of the way of being pinched by the bony margins. The triceps muscle acts similarly for the posterior fibers. The capsule is lined by synovial membrane which is continued into the fossæ about the joint.

This is a hinge joint, allowing flexion and extension around an oblique axis inclined at an angle of 84 degrees with the shaft of the

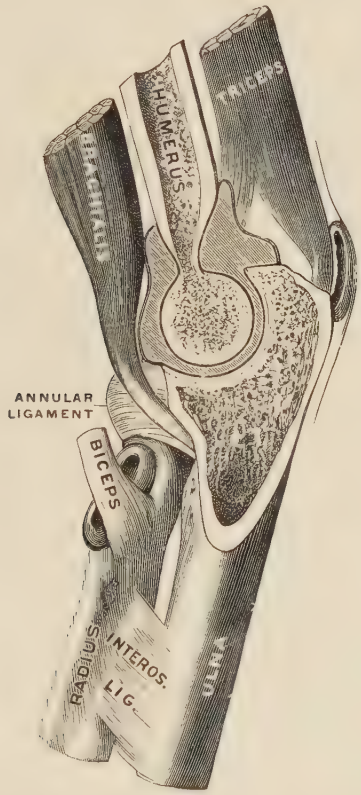


FIG. 110.—Elbow-joint in sagittal section, showing the articular synovial sac and the bursæ of the olecranon and the biceps. (Testut.)

humerus. In flexion of the forearm, the hand moves toward the middle line of the body, and *vice versa* in extension. The head of the radius moves on the capitellum and aids in preventing side displacement of the bones. In the semi-flexed position of the elbow movement of the radial head in pronation and supination is most free.

The tendons of the biceps, brachialis and triceps muscles do much to strengthen this joint (Fig. 110).

The Radio-ulnar Articulations.—The radio-ulnar articulations consist of two joints and a fibrous union. The *superior,* formed by the head of the radius pivoting in the lesser sigmoid cavity of the ulna, has the orbicular ligament surrounding, and holding it as in a sling. Its movements in connection with the inferior radio-ulnar articulation are pronation (turning the palm downward) and supination (turning the palm upward).

The fibrous union between the two bones of the forearm consists of an oblique band above and the interosseous ligament below, extending to the lower articulation. As these fibers are obliquely placed the space between the bones is greater during supination.

The *inferior* radio-ulnar joint is formed by the head of the ulna in the sigmoid cavity of the radius. It is closely associated with the wrist-joint by the triangular fibrocartilage which connects the radius and ulna and separates the ulna from the wrist-joint. It is enclosed by a capsular ligament. The lower end of the radius moves about the ulna in rotation, carrying the hand with it.

The Wrist-joint.—The wrist is a condyloid joint, formed by the lower end of the radius and the carpal bones, *scaphoid* and *semilunar.*

The lower end of the ulna is separated from the joint by the triangular fibrocartilage, the lower surface of which articulates with the upper surface of the *cuneiform.*

Bands of fibers, anterior, posterior, internal and external lateral form a capsule lined by synovial membrane. The posterior aspect of the joint is strengthened by the extensor tendons.

The Carpal Articulations.—The carpal articulations consist of bands of fibrous tissue connecting the various carpal bones to each other, front, back and in between. Fibers between the carpal and metacarpal, the metacarpal and phalanges are on all sides. The phalanges are united with each other by capsular ligaments.

Movements of the wrist-joint are flexion, extension, abduction, adduction and circumduction, but not rotation.

The carpal bones form gliding joints with each other, and provide considerable elasticity, which lessens shock. Exclusive of the first and fifth, the carpo-metacarpo joints allow flexion and extension. The fifth provides for a greater amount of these movements, and the direction of the flexion is outward, so cupping the hand and causing opposition of the little finger. The joint of the metacarpal of the thumb and corresponding carpal bone is of reciprocal reception, with flexion, extension, abduction, adduction and circumduction. Flexion is obliquely forward and inward allowing the opposition of the thumb to any of the fingers.

The metacarpo-phalangeal joints are condyloid, with the usual movements, excepting that the first allows only flexion and extension.

The various joints of the hand combine to allow prehension and a variety of movements characteristic of man.

THE PELVIC ARTICULATIONS.

The fifth lumbar vertebra articulates with the upper surface of the sacrum, and very strong ligaments hold them together. The fibrocartilaginous disk between them is especially thick so allowing free flexion and extension, as in sitting or in rising from the sitting position. The inclination of the pelvis depends partly upon the relative position of these bones. The articulations between the sacrum and coccyx and between the segments of the coccyx allow a small amount of motion.

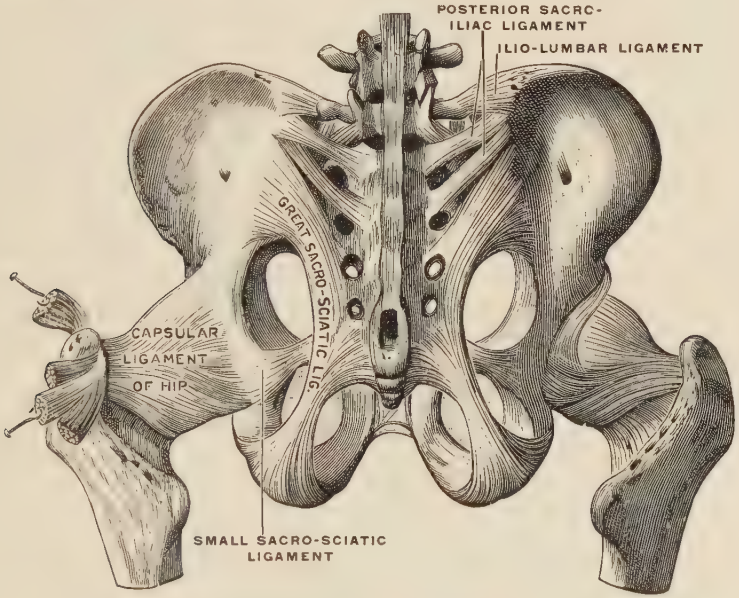


FIG. 111.—Articulations of the pelvis, rear view. (Testut.)

The Sacro-iliac Synchondrosis.—The sacro-iliac synchondrosis is formed by the union of their two auricular surfaces, connected by very strong ligaments, especially those posterior. Under normal conditions no motion is possible between these bones.

The obliquity of the pelvis is modified by the relation of these bones, also.

The Symphysis Pubis.—The symphysis pubis, or joint between the two pubic bones, has a disk of fibrocartilage between, with ligaments above, below, front and back. No movement is allowed.

THE ARTICULATIONS OF THE LOWER EXTREMITY.

The Hip-joint.—The hip-joint is analogous to the shoulder-joint in the upper extremity. It is formed by the rounded head of the

femur, and the acetabulum. The surfaces are prepared by the covering of cartilage. Around the edge of the acetabulum is a rim of fibrocartilage, the *cotyloid* ligament, which deepens the cavity to better fit the head of the femur. The notch at the lower border is bridged by the transverse ligament, forming a foramen through which passes nerves and bloodvessels. Attached to the head of the femur and going to the bottom of the cavity is a band, the *ligamentum teres*, which holds the femur in the socket, even after the capsular ligament is removed. Coming from the rim of the acetabulum,

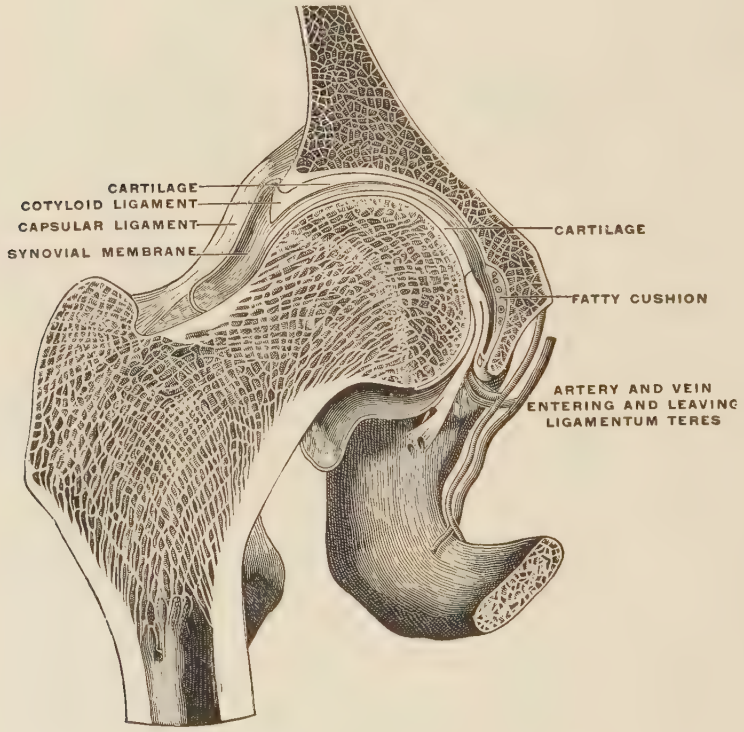


FIG. 112.—Hip-joint in coronal section. (Testut.)

beyond the cotyloid ligament is a sheath of fibrous tissue, the *capsular* ligament. This extends to the anterior intertrochanteric line in front, and half an inch internal to the posterior intertrochanteric line behind. On the outside of the capsule are three accessory bands, of which the first is most important. The *ilio-femoral* band, or "Y" ligament of Bigelow, is shaped like an inverted "Y" with the stem attached to the anterior-inferior iliac spine, and the wide lower end to the anterior intertrochanteric line. The *pubo-femoral* band passes from the pubic bone to the femur. Between

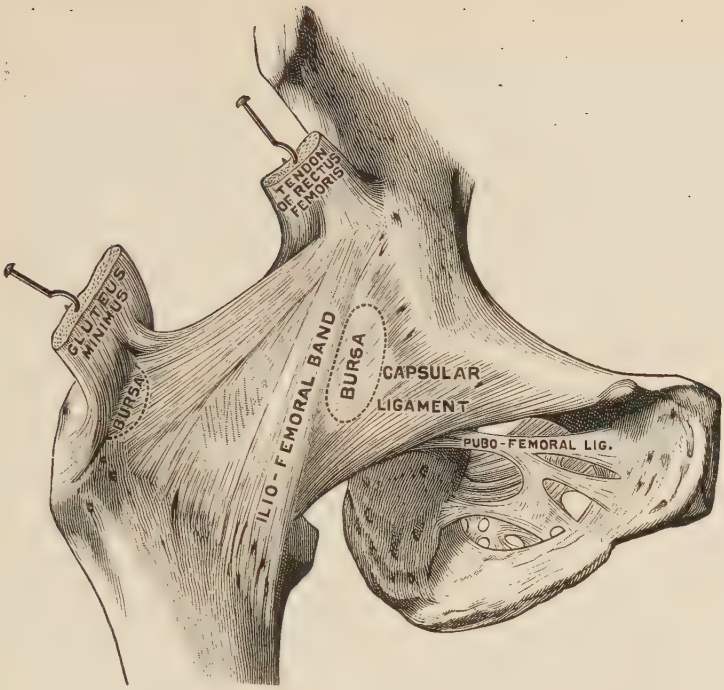


Fig. 113.—Hip-joint, front view. The cavity is distended artificially. (Testut.)

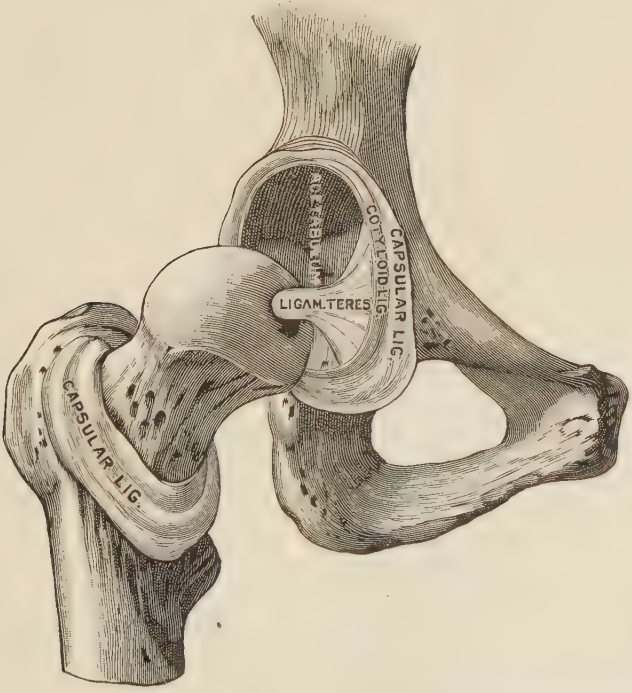


Fig. 114.—Hip-joint, front view. The capsular ligament has been largely removed. (Testut.)

this and the ilio-femoral band, the capsule is thinner and weaker, allowing dislocation. This provision may prevent greater injury to the joint, from external violence.

The third accessory band, the *ischio-femoral* passes from the ischium just below the acetabulum to the base of the great trochanter.

The capsule is further strengthened by fibers from the tendinous sheath of various muscles. The ilio-psoas in front; the pectineus on the inner side; obturator externus behind and below; obturator internus, two gemelli and pyriformis behind and the rectus femoris and gluteus minimus externally. The capsule is lined by a synovial membrane, which is reflected on to the neck of the femur and surrounds the *ligamentum teres.* This ball-and-socket joint allows all movements though their extent is less than those of the shoulder-joint.

Flexion and extension occur without the head of the femur leaving the socket. This is true for none of the other movements. Extension is limited by the "Y" ligament, which also helps to prevent the trunk falling backward. If the knee flexes at the same time, flexion takes place to 140 degrees, until limited by the contact of the thigh with the abdominal wall. If the knee is extended, the resistance of the hamstrings stops the movement at 90 degrees.

The Knee-joint.—The knee-joint is formed by the condyles of the femur, the upper surface of the tibia and the patella.

To the cartilage covered surface of the tibia two disks of fibro-cartilage, somewhat horse-shoe shaped, and called *semilunar* cartilages are applied to deepen the cavity. The disks are thicker on the outer edges, at which they are loosely attached to the bone by the *coronary* ligaments, with the *transverse* ligament going from one to the other in front.

The bones are held together by two *crucial* ligaments, anterior and posterior which arise from in front of, and behind the spine of the tibia, and are inserted into the contiguous surfaces of the two condyles. The *patella,* a sesamoid bone in the tendon of the quadriceps extensor cruris muscle, forms the front part of the joint, and moves up and down over the trochlear surface of the femur, in extension and flexion of the joint.

Surrounding the joint are bands on all sides, which are connected by additional fibers to form a complete capsule. The tendon of the quadriceps muscle, inserted into the tubercle of the *tibia* and sometimes called the *ligamentum patellæ* forms the front part of the capsule. Posteriorly, oblique fibers, the *ligamentum Winslowii;* laterally, one internal, two external ligaments complete the covering of a joint that is said to be made up of three joints fused together.

A most extensive synovial membrane lines the capsule, covers the semilunar cartilages and crucial ligaments. It communicates

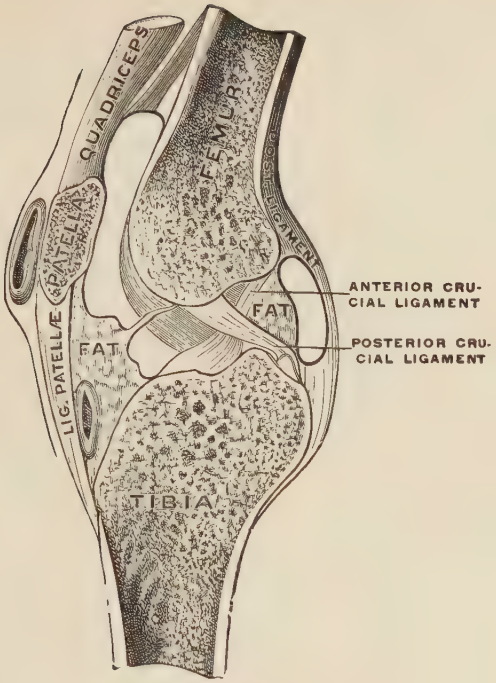


FIG. 115.—Knee-joint in sagittal section. (Testut.)

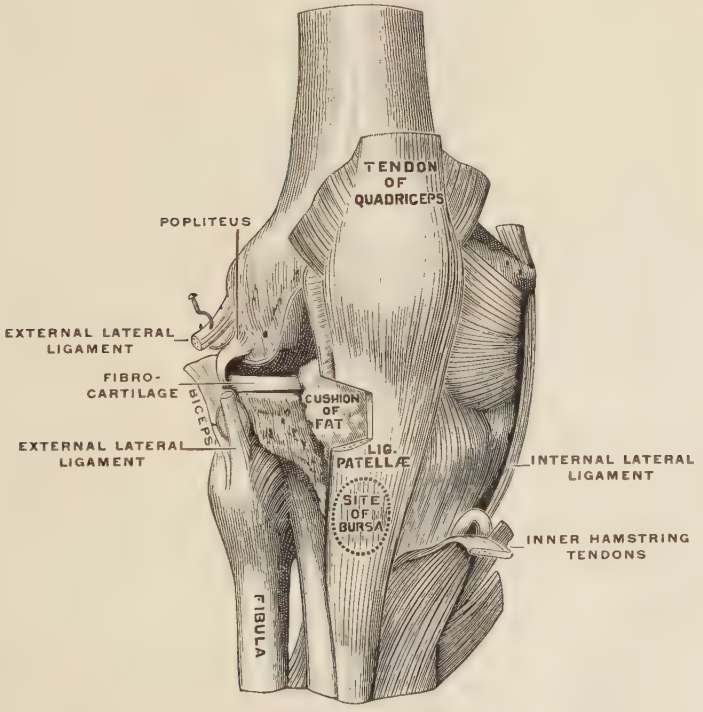


FIG. 116.—Knee-joint, front view. Part of the ligaments have been removed on the right side. (Testut.)

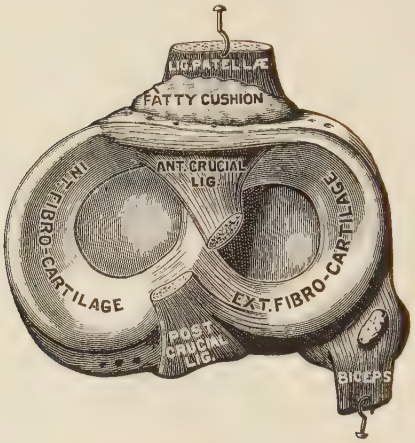


FIG. 117.—The semilunar cartilages of the right knee-joint. (Testut.)

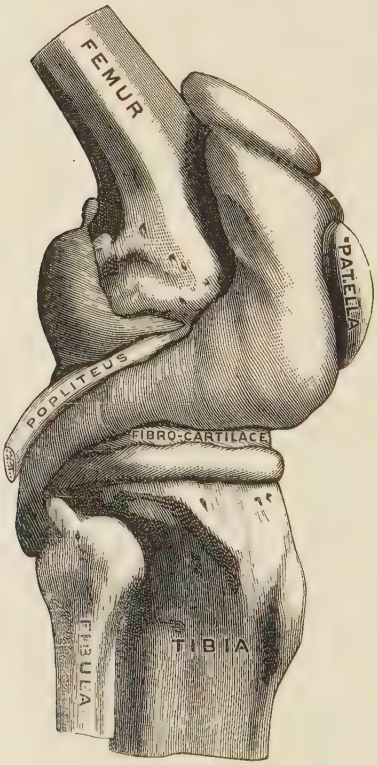


FIG. 118.—Knee-joint, outer side. The synovial sacs are artificially distended. (Poirier.)

with numerous bursæ around the joint, and forms a crescentic fold within the joint called the *ligamentum mucosa*. This projects from the front of the capsule backward and upward to the front of the intercondyloid notch. The ends of the fold form the *alar ligaments*. Small masses of fat help to fill the spaces between the bones and to form cushions.

The knee-joint has many bursæ, some of which communicate with the main synovial cavity. Some of the most constant and important ones are those between the bones and the tendons passing on each side of the popliteal space; above and beneath the *ligamentum patellæ;* over the patella; between the inner hamstring and the head of the tibia, and over the tubercle of the tibia.

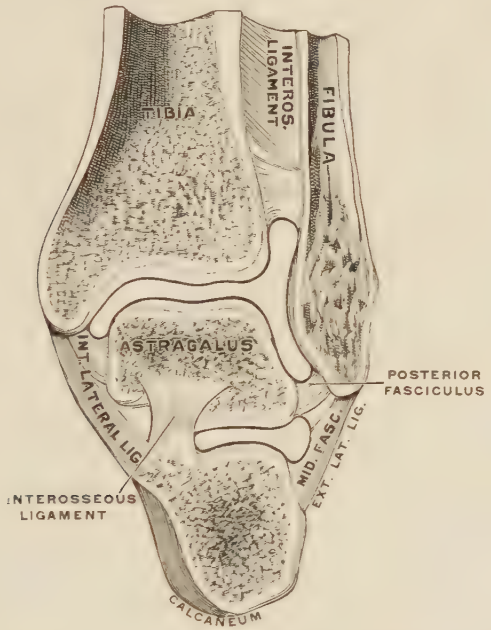


FIG. 119.—Tibio-tarsal and calcaneo-astragaloid articulations, in coronal section. The synovial sacs are distended. (Testut.)

The knee is a modified hinge-joint with flexion and extension around an axis that shifts forward in flexion and backward in extension. On account of the shallowness of the cavities on the upper surface of the tibia and the curves of the condyles, the surfaces cannot remain in constant close contact. During flexion, the crucial ligaments become tense, and pull the tibia backward, making the points of contact between the bones more to the front. By this means, relaxation of the ligaments follows, and the movement is allowed to continue. The flexor muscles of the joint tend to pull

the tibia back, but this is opposed by the posterior crucial ligament, while the anterior crucial opposes the opposite pull of the quadriceps muscle toward the front. At the end of the movement of extension, there is a slight outward rotation of the leg, shown by the outward pointing of the foot. This is reversed at the beginning of flexion. In descending a slope, the foot naturally turns out, and *vice versa*. The tendons of the quadriceps, the hamstrings, inner and outer, the gastrocnemius and the popliteus muscles serve as supplementary ligaments to protect this joint. They are so adjusted that over-extension of the joint is resisted by them, enabling the body to maintain the erect position with little muscular effort.

The Articulations of the Tibia and Fibula.—The articulations of the tibia and fibula are in three parts, upper, lower and middle. Bands of fibers passing from bone to bone join the head of the fibula to the facet on the outer tuberosity of the tibia. An interosseous membrane connects them throughout their length. The oblique direction of these fibers allows a slight gliding of the bones on each other, so that during flexion of the ankle there is a widening of the mortise part of the mortise and tenon of the ankle. The lower articulation merits a careful consideration.

Ankle-joint.—This is formed by the *internal* and *external malleoli* and the *astragalus*. The lower ends of the tibia and fibula form a mortise into which the astragalus fits as a tenon, giving a very strong structure to prevent lateral displacement and resist the tremendous leverage exerted by the height and weight of the body. The joint is closed in by a capsule, with ligaments on all four aspects, especially lateral.

The anterior fibers pass from the front of the tibia to the upper part of the astragalus; the posterior fibers from the back in the same way. The external lateral is divided into three fasciculi, anterior, middle and posterior. The anterior bundle passes from the front of the external malleolus to the front of the astragalus; the middle bundle from the tip of the external malleolus to the os calcis; the posterior from the back of the malleolus to the outer surface of the astragalus. The internal lateral or deltoid ligament is triangular in shape attached by its apex to the tip of the internal malleolus, with its base inserted on the inner surface of the astragalus, the sustentaculum tali of the calcaneum, the scaphoid and to the inferior calcaneo-navicular ligament.

The tendons of the muscles that move the ankle-joint, the tarsal joints and the toes are in close relation to this joint, and act as supplementary ligaments. Bursæ lie between the skin and the two malleoli.

A hinge movement is permitted in the ankle-joint, to less than 90 degrees. The axis of this movement is slightly oblique, and so helps to secure a stable equilibrium in standing. The movements

of the ankle-joint are closely associated with those of the medio-tarsal articulation and the combined action of the muscles acting on both has much to do with maintaining the balance in both standing and walking.

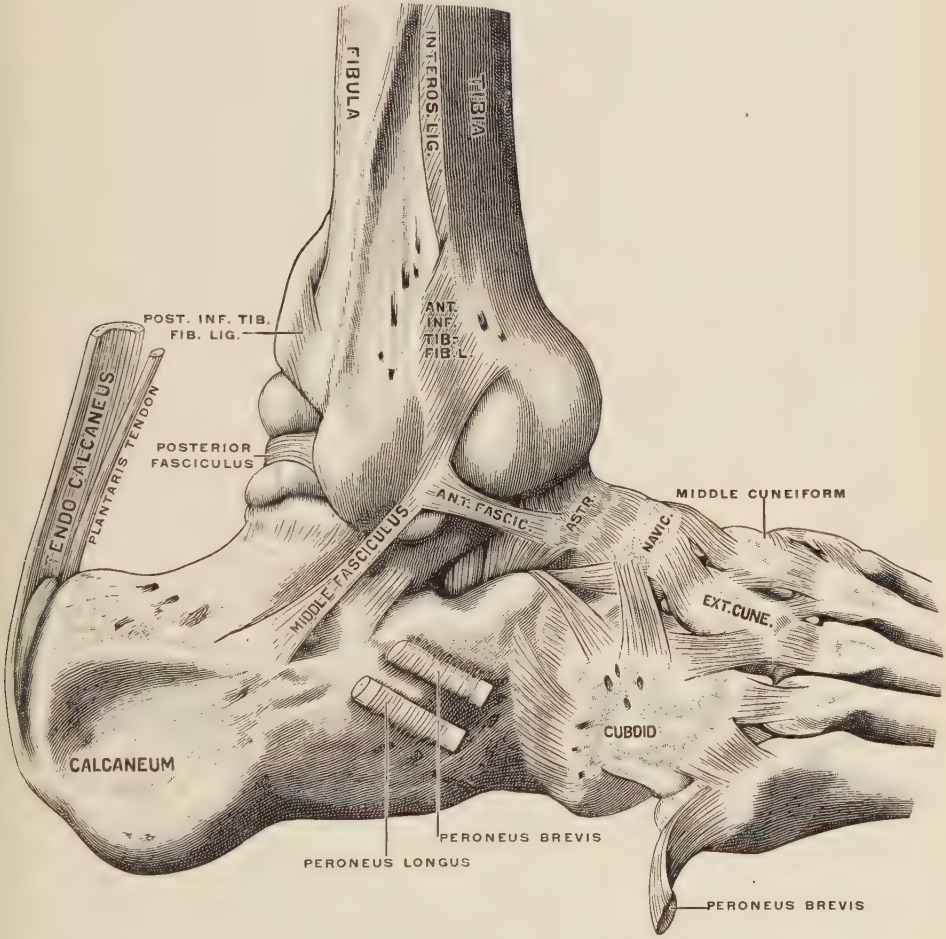


FIG. 120.—Tibio-tarsal articulation, outer side. The cavity is artificially distended. (Testut.)

The Tarsal Articulations.—As in the carpal joints, the various bones of the foot are held together to form gliding joints which allow a small amount of motion, but provide for elasticity and shock absorption. The articulation of the astragalus with the calcaneum and the scaphoid, and of the cuboid with the calcaneum should receive attention. Posteriorly and externally the first two are

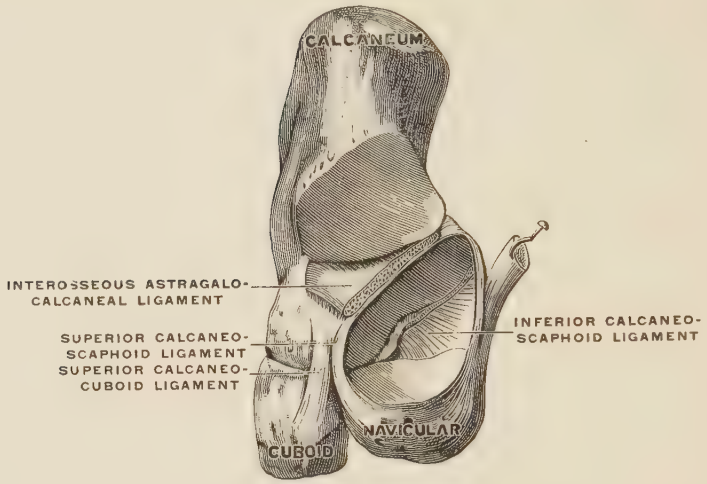


FIG. 121.—Medio-tarsal joint, viewed from above, the astragalus having been removed. (Testut.)

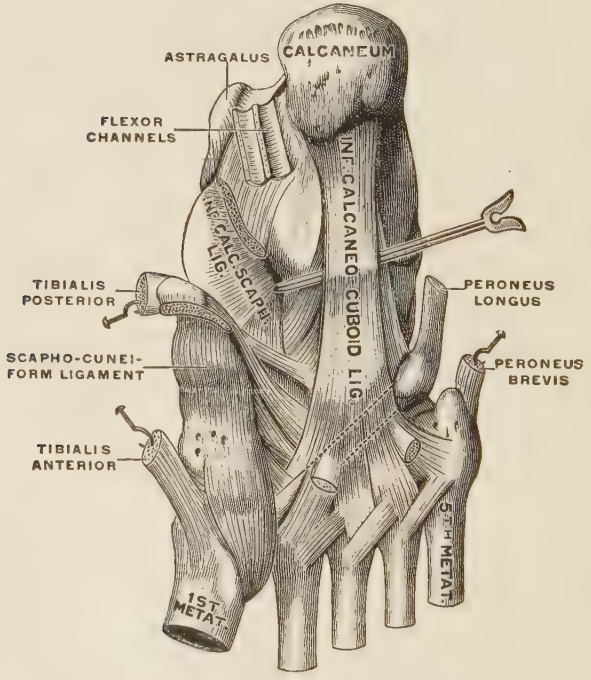


FIG. 122.—The plantar ligaments. (Testut.)

joined by bands of fibers, and on the anterior and inner aspect the calcaneum, astragalus and scaphoid are united. Between the calcaneum and the scaphoid are the inferior and superior calcaneo-scaphoid ligaments which are partly cartilaginous (hence elastic) giving support to the head of the astragalus which rests upon them.

The calcaneo-cuboid articulation on the outer side of the foot, with the astragalo-scaphoid union, forms a joint right across the foot, separating the front from the hind part and is called the medio-tarsal articulation. The bones are connected on the dorsal surface, and on the plantar surface are two ligaments, the *plantar* ligaments, which form the inferior calcaneo-cuboid ligament. The long and short plantar ligaments connect the under surface of the calcaneum with the under surface of the cuboid, and have much to do in maintaining the normal arches of the foot.

The movements at the calcaneo-astragaloid joint are inversion, eversion, adduction and abduction. These also occur in the medio-tarsal joint as well as flexion and extension.

Flexion at the medio-tarsal is associated with extension at the ankle, and the reverse. The joint between the astragalus and scaphoid is a ball-and-socket, but its motion is limited by its association with the condyloid joint between the calcaneum and cuboid.

In the medio-tarsal joint, flexion of the foot is combined with inversion of the sole and adduction of the front of the foot. If this position is exaggerated and permanent, the condition of "club foot" results. If the reverse obtains, or extension with eversion of the sole and abduction of the front, the "flat foot" or "pronated foot" is produced.

The three cuneiform bones are united to all the bones in contact with them, and produce gliding joints. In the tarso-metatarsal joints, slight flexion, extension, abduction and adduction, obtain with greater freedom in these movements between the metatarso-phalangeal joints. Abduction and adduction take place from and toward the middle of the second toe. The interphalangeal joints allow flexion and extension, only. The mechanism of the foot is designed for standing and locomotion. The balanced action of the various muscles acting upon the ankle and bones of the foot, should hold it in a position in which the ligaments are not strained, but in which the long and transverse arches operate to insure elasticity and strength.

THE RELATION OF MUSCLES AND TENDONS TO JOINTS.

Under ordinary conditions the ligaments are sufficient to hold together the bones which form a joint. They do not prevent displacement or dislocation under sudden, severe strain, or from long-continued moderate strain. The provision for further pro-

tection is found in the muscles and tendons which pass over the joint. These are held in close contact with the joint by the deep fascia which is continuous with the fibrous tissue of which the ligaments are composed.

Notice where the tendon of insertion of the biceps humeris comes, in relation to the elbow-joint, as well as the location of the two points of origin at the shoulder-joint. When the biceps contracts it prevents the head of the humerus from slipping forward out of the glenoid fossa. It also helps to keep the radius from slipping off the capitellum.

The more motion the joint is allowed by its structure, the more completely it is guarded by muscles. Suddenly applied external force, acting on a joint when the muscles are "off guard" is likely to produce dislocation.

A demonstration of this may be made by grasping an overhead bar, and letting the weight hang loosely. Care must be taken to keep the feet on the floor, so too much of the weight is not so suspended.

In "faulty standing" the weight depends upon "ligamentous support, instead of upon tonic muscles. This may result in more or less bony displacement, as "sprung knees."

QUESTIONS.

Describe a typical *joint.*

What *movements* are possible in joints?

How much movement is possible in the *spinal column,* and in what direction?

What *articulations* provide for the movements of the head?

Describe the shoulder-joint.

What joints provide for pronation and supination of the hand?

What relation has the strength of the ligaments of the sacro-iliac synchondrosis to the maintenance of the erect position?

Compare the structure and movements of the hip- and shoulder-joints.

What are the "semilunar cartilages?"

What are the "crucial" ligaments?

How many joints are combined in the knee-joint?

Describe the ankle-joint..

What movements of the foot take place at the tarsal and medio-tarsal joints?

What are the articulations of the thorax, and how are the movements related to respiration?

How does Nature provide for the dislocation of a joint to save greater injury?

CHAPTER V.

THE MUSCULAR SYSTEM.

The skeletal muscles almost completely envelope the framework of the body, cover the abdominal cavity, separate the thoracic from the abdominal cavities, and are connected with the oral cavity, the nose, ear and throat. Two-fifths of the weight of the body consists of the voluntary muscular system.

The size and shape of muscles varies according to their work, being broad and thin to cover cavities, and longer and narrower when moving such parts as the extremities.

The muscles are covered by sheaths of fibrous tissue, called fasciæ. This is divided into the superficial and deep layers, according to location. The superficial layer is directly under the skin, while the deeper layer covers the muscles, dipping down between them, and forming so-called *intermuscular septa*. This deep fascia holds the muscles together, and aids them in their work of coördination. It frequently gives a definite area of attachment to the muscles.

The relation of the fascia to the veins that drain the extremities will be considered a little later in connection with the circulation.

Muscles are composed of bundles of fibers, reddish in color, each surrounded by a sheath of fibrous tissue. This sheath extends beyond the fiber, and the aggregation of extensions forms a tendon of attachment to a bone, cartilage or fascia. The fleshy portion of a muscle is called the "belly," and it is the active part. The tendinous portion is inactive, and transmits passively the pull developed by the contraction of the fleshy portion. Every fiber has its own nerve supply, with the minute nerve fibers uniting into a bundle which is between the bundles of muscle fibers.

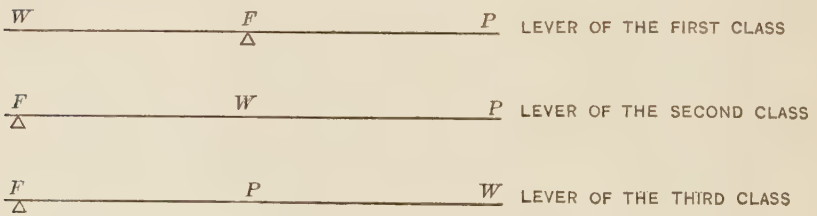
In some muscles, as the rectus abdominis, tendinous inscriptions, so-called, pass across the belly, adding to their strength. The tendons vary in shape from long cords to thin and broad sheets called *aponeuroses*, having in general a similarity to the form of the muscles of which they are a part.

The various movements of the body are caused by the contraction of muscles. As a muscle contracts it becomes shorter and broader. The tendons being inextensible do not change in shape, but transmit the pull to the structures to which they are attached, as bone, fascia, etc. These are moved toward each other, though one end is usually moved less than the other.

It is customary to speak of the fixed end as the origin and of the moving end as the insertion, but while this is convenient it is not always true to fact, as the conditions are frequently reversed. These terms are also used to indicate the proximal and distal ends of the muscle, the origin being that attachment nearest the center of the body or nearest the head, and the insertion that more distant.

The point of application of power is also called the insertion. The application of the power of muscles should be considered from the standpoint of mechanics. The bones and muscles constitute a series of levers.

Briefly a lever is a means of applying power to obtain movement more or less economically. If one wants to move a heavy stone, and is unable to lift it in his arms, a lever can be arranged that makes it easy to accomplish. By inserting the end of a bar under the edge of the stone and pressing down upon the further end of the bar, the stone is easily moved. The leverage of the bar increases the power of the individual many fold. The saying of Archimedes becomes comprehensible, *i. e.*, "Give me a place upon which to stand and a long enough lever, and I will move the earth." Levers are divided into three classes, according to the relative position of the weight to be moved, the power to move it and its point of application, and the fulcrum about which it is moved. Let F represent the fulcrum; W the weight and P the power, and the lever in which F is in the middle is of the first class. That in which the weight is in the middle is of the second class, and that in which the power is in the middle is of the third class. The following diagram will make this clear.



The majority of the muscles of the body belong to the third class of levers. This is rather wasteful of power, but there are compensating advantages that more than make up for this. Greater speed of movement is obtained, more beauty of form, greater convenience in use and increased security of joints.

Muscles passing over more than one joint are said to have a primary action on the first joint, a secondary action on the next, and a tertiary action on the third if the contraction continues. For instance, the flexor of the fingers that is inserted in the base

of the last phalanx of the finger, has a primary action on the joint next above; a secondary action on that further up and a tertiary action on the metacarpo-phalangeal joint.

LIGAMENTOUS ACTION OF MUSCLES.

In the lower extremity certain muscles which pass over two joints serve as extensors of one and flexors of the other, by the so-called "ligamentous action." Such muscles are known as "two-joint muscles." See notes on page 174 in reference to the flexors of the leg.

The usual action of a muscle from a fixed origin to a movable insertion is called its *direct* action, but when a fixed insertion acts upon a movable origin, the action is called its *reversed* action.

TONICITY OF MUSCLES.

In a living animal, if a muscle is cut, the two ends separate. This indicates a condition of slight contraction, which, to a greater or less degree is constant. It is called *muscle tonus*, or tonicity, and is manifest as more or less firmness or hardness of consistency. The muscle is thereby enabled to promptly respond to stimulation. Vigorously used muscles are more "tonic" than those that have little exercise.

The opposite condition is *flaccidity*, which occurs when motor impulses are cut off from the muscle, as in "infantile paralysis." This is characterized by a marked softness of consistency.

The normal tonus is apparently a reflex, depending upon slight afferent impulses from the periphery reaching cells in the spinal cord, and slight motor impulses going thence to the muscles.

Nervous Stimuli.—The normal stimulus through which muscles contract is that from the motor nerves.

A single message is followed by a single contraction and subsequent relaxation. The stronger the stimulus, the greater the contraction. With stimuli of the same intensity, the contraction increases with several repetitions. This is supposed to be due to the stimulating effects of the waste products developed in the muscle fiber. But, as contraction proceeds, and waste products accumulate, fatigue develops, and there is a marked lessening of the work done.

Up to a certain point, the more resistance a muscle is given, or the greater its load, the stronger is its contraction. Passing that point, increases in the load lessens the power and the work done.

The rapid repetitions of nervous stimuli produces a continued contraction, during which there is no relaxation of the muscle. A sustained effort of the will in holding a muscle contracted implies a long series of efferent impulses following each other without pause.

Chemical Changes.—During muscular contraction a greater amount of O is absorbed by the muscle plasma, and an increased quantity of CO_2 is given off. The reaction changes from alkaline to acid by the development of sarcolactic acid. More blood flows to and from the muscle in a given unit of time. The amount of urea does not appear to be increased unless, on account of a deficiency of carbohydrates in the diet, protein food has had to be used as a source of energy.

The energy developed in the form of heat is some four times that developed as motion.

THE NAMING OF MUSCLES.

There are various considerations entering into the nomenclature of muscles, as action, shape, location, relative size, attachments, direction of fibers, etc. For instance, *pronator teres* indicates both the action as a pronator of the forearm and its round shape as distinguished from the quadratus or square pronator. The *pectoralis major* indicates the location on the chest wall, and the greater size of this muscle as compared with the minor pectoral.

The *brachio-radialis* indicates the bones to which the muscle is attached, the *obliquus externus abdominis* indicates the oblique direction of the fibers, as well as its external position on the abdominal wall, as compared with the interior position of the *obliquus internus abdominis*.

Attention to these names and their meanings will help to fix the actions of the various muscles in the memory. All muscles are given Latin names, as making them intelligible to scientific students everywhere.

MOVEMENTS OF MUSCLES.

The movements produced by muscles always involve several acting together, with still others holding the points of origin firm and others controlling the speed and range of the movement. In studying the action, then, of any particular muscle, there must be included the consideration of the antagonistic and the fixator muscles also.

The movement of *flexion* is produced by *flexor* muscles, with the opposite *extension* produced by *extensor* muscles. *Abductor* muscles oppose *adductors*, and *pronators* oppose *supinators*. *Inward rotators* oppose *outward rotators*. The movement of circumduction is a combination of flexion, extension, abduction and adduction. It may vary in direction, inward or outward, but muscles are not named as producing this movement.

METHODS OF STUDY.

If the conformation of the bones has already been fixed in the mind's eye, by actual use of the bones during the study of the osseous system, it will render easier the study of muscles. After learning the attachments of muscles, and finding the bony markings, paper or cloth patterns cut out in the size and shape of the muscles and applied to the skeleton, give a vivid idea of reality. The use of rubber bands or strings attached to the skeleton and made to imitate the muscular pull is also recommended. But the skeleton is not always available for study, but our own bodies are. Most of the superficial muscles can be felt contracting, and continuous examination of the areas contracting will help greatly in this study.

MOVEMENTS OF THE SEGMENTS OF THE UPPER EXTREMITY.

The *shoulder-girdle* moves upward, downward, forward and back upon the articulation of the clavicle with the sternum. The terms *elevation, depression, abduction* and *adduction* are used to indicate these movements.

The *arm* moving at the shoulder-joint is raised forward in *flexion,* backward in *extension,* outward in *abduction* and inward in *adduction, inward* or *outward* in *rotation* and *circumduction.* The *forearm* moving at the elbow-joint is raised forward in *flexion,* and returns to the straight line in *extension.* (It should be noted that all the joints of the body when at rest are in a position midway between flexion and extension, or whatever other position is allowed.)

At the upper radio-ulnar joint, the forearm turns inward in *pronation,* outward in *supination.*

The *hand* moving at the wrist goes forward in flexion, backward in extension, outward in abduction and inward in adduction, while circumduction may be inward or outward. (Attention is called to the fact that in describing movements or positions the body is supposed to be standing erect, with arms hanging at the sides with the palms facing forward.) The *fingers* moving forward at the various phalangeal joints are in flexion, while the opposite movement is extension. This is true at the metacarpo-phalangeal joints, also, at which abduction and adduction occur from and toward the middle line of the second finger.

The *thumb* bends toward the little finger in flexion, crossing the palm, and the reverse in extension. This is on account of the forward position of the first metacarpal bone, so the thumb is almost at a right angle with the fingers. Abduction of the thumb is toward the rear, while adduction is in the opposite direction.

In these movements of the upper extremity, flexion is movement *forward,* but in the lower extremity, flexion and extension alternate

in the forward direction, in the successive joints. The explanation lies in their different functions, prehension in the upper and locomotion and balance in the lower members.

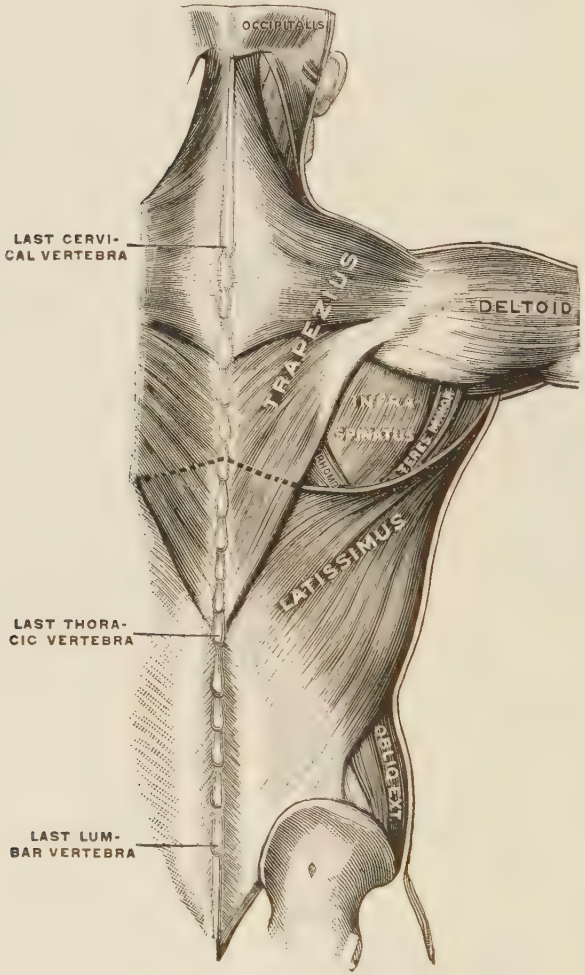


FIG. 123.—Muscles in the superficial layer of the back. (Testut.)

THE MUSCLES MOVING THE SHOULDER.

Upward and backward.
Trapezius
Levator scapulæ
Rhomboideus minor and major

Downward and forward.
Serratus magnus
Pectoralis minor
Subclavius

Trapezius.—In three parts. (Fig. 123.)

Location.—Superficial on upper back and shoulder.

Origin.—Superior curved line and protuberance of occiput; ligamentum nuchæ; spines of seventh cervical and twelve thoracic vertebræ.

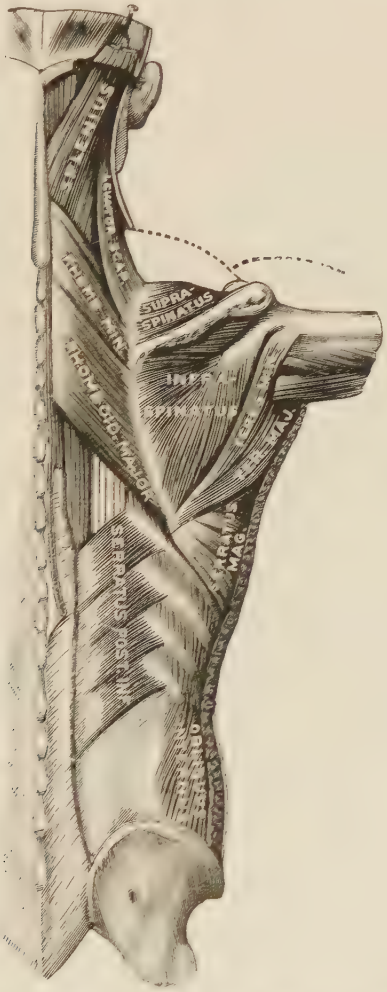


FIG. 124.—Muscles in the second layer of the back and on the dorsum of the shoulder. (Testut.)

Insertion.—Outer third of posterior border of clavicle. Inner border of acromion and upper border of spine of scapula. Tubercle of spine near its inner end.

Nerve Supply.—Spinal accessory and third and fourth cervical.

Action.—With head fixed, upper fibers lift outer end of clavicle with scapula. With scapula fixed, one side rotates the head; both sides pull the head backward.

Middle fibers, lift acromion; adduct scapula.

Lower fibers, pull vertebral border of scapula down and in. As a whole, rotates scapula to turn the glenoid fossa upward and outward.

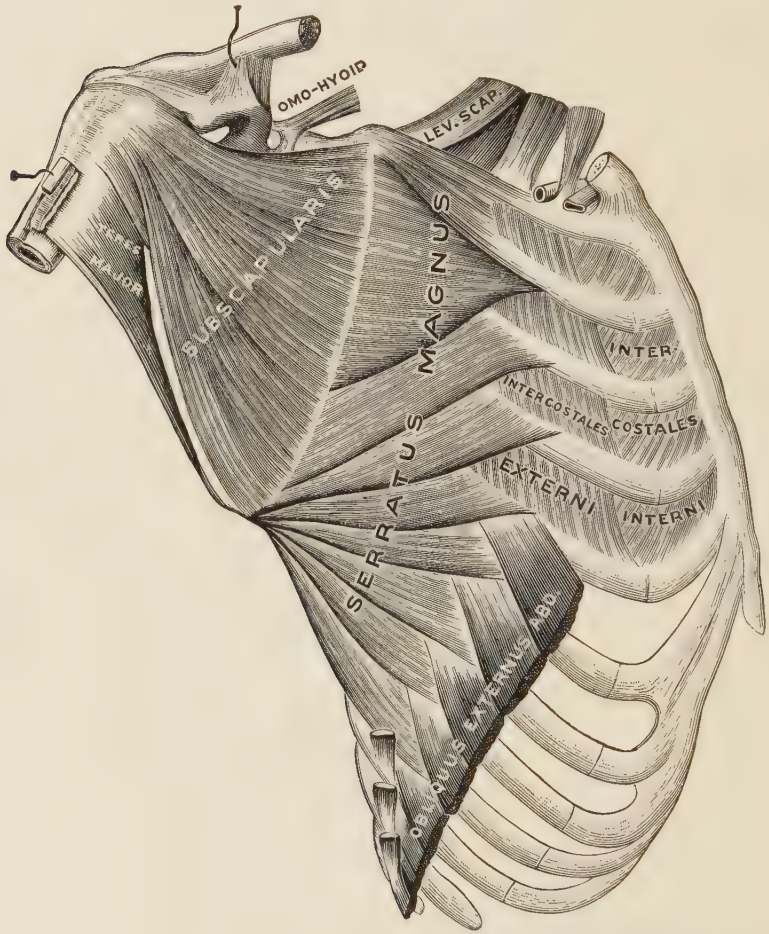


Fig. 125.—Serratus magnus of right side. The scapula has been turned backward and drawn outward. (Modified from Testut.)

Levator Scapulæ.—(O. T. levator anguli scapulæ). (Fig. 124.)

Location.—On the side of the neck, under the trapezius.

Origin.—Upper four or five cervical vertebræ, on transverse processes.

Insertion.—Vertebral border of scapula from superior angle to root of spine.

Nerve Supply.—Third, fourth and fifth cervical.

Action.—Lifting upper angle of scapula with depression of the outer end.

Rhomboideus Minor. (Fig. 124.)

Location.—Between the scapula and spine, underneath the trapezius.

Origin.—Ligamentum nuchæ; spines of seventh cervical and first thoracic vertebræ.

Insertion.—Vertebral border of scapula at root of spine.

Nerve Supply.—Fifth cervical.

Action.—Adducts and elevates the scapula with some rotation.

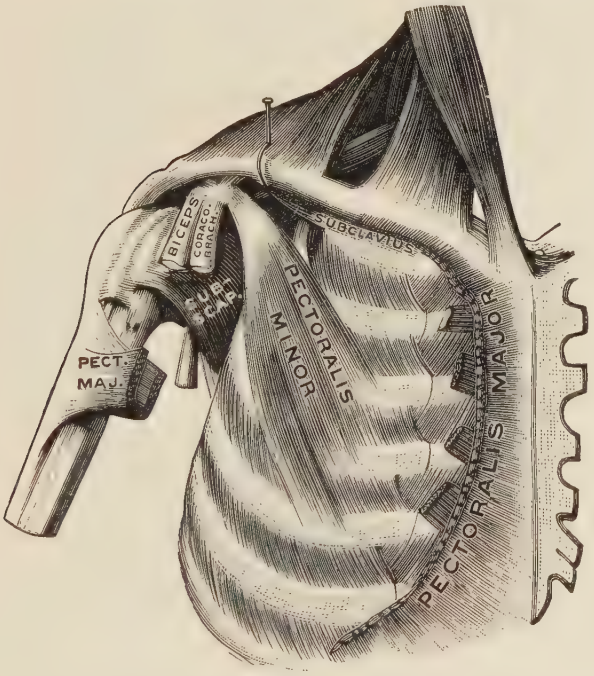


FIG. 126.—Pectoralis minor of right side. (Testut.)

Rhomboideus Major. (Fig. 124.)

Location.—Just below the minor.

Origin.—Spines of the upper four or five thoracic vertebræ.

Insertion.—Vertebral border of scapula, below that of the minor.

Nerve Supply.—Fifth cervical.

Action.—Adducts and elevates the scapula.

Serratus Magnus.—(Fig. 125.)

Location.—Anterior to the scapula on the upper side of the chest.

Origin.—By digitations, in three parts.

Upper part, from first and second ribs, several inches from their costal cartilages.

Middle part, from second and third ribs.

Lower part, from fourth to eighth ribs.

Insertion.—Upper part to ventral border of the superior angle.

Middle part to ventral surface of vertebral border, except angles.

Lower part to ventral border of the lower angle.

Nerve Supply.—Posterior thoracic.

Action.—The upper and middle parts draw the shoulder forward as in pushing, while the lower part rotates the scapula, turning the glenoid fossa upward as in raising the arm.

Pectoralis Minor. (Fig. 126.)

Location.—On the front wall of the chest, covered by the large pectoral.

Origin.—Third, fourth and fifth ribs, near their cartilages.

Insertion.—Coracoid process of the scapula.

Nerve Supply.—Internal anterior thoracic.

Action.—When chest is fixed, draws scapula down and forward. When scapula is fixed, draws the chest upward, as in forced inspiration.

Subclavius. (Fig. 126.)

Location.—Under the clavicle.

Origin.—The first rib and its cartilage.

Insertion.—A groove on the under surface of the clavicle.

Nerve Supply.—Fifth and sixth cervical.

Action.—Depresses the scapula and turns the glenoid fossa downward.

THE MUSCLES MOVING THE ARM.

Abductors.	*Adductors.*
Deltoideus	Pectoralis major, Coracobrachialis } also flexors
Supraspinatus	Latissimus, Teres major } also extensors
Outward rotators.	*Inward rotator.*
Infraspinatus	Subscapularis
Teres minor	

Deltoideus. (Fig. 127.)

Location.—Forming a cap over the shoulder-joint.

Origin.—Anterior border of the outer third of the clavicle. Acromion process, and lower border of the spine of the scapula.

Insertion.—The deltoid impression, midway of the outer surface of the humerus.

Nerve Supply.—The circumflex.

Action.—Abduction of the arm. The anterior fibers carry the arm forward, the posterior fibers carry it backward.

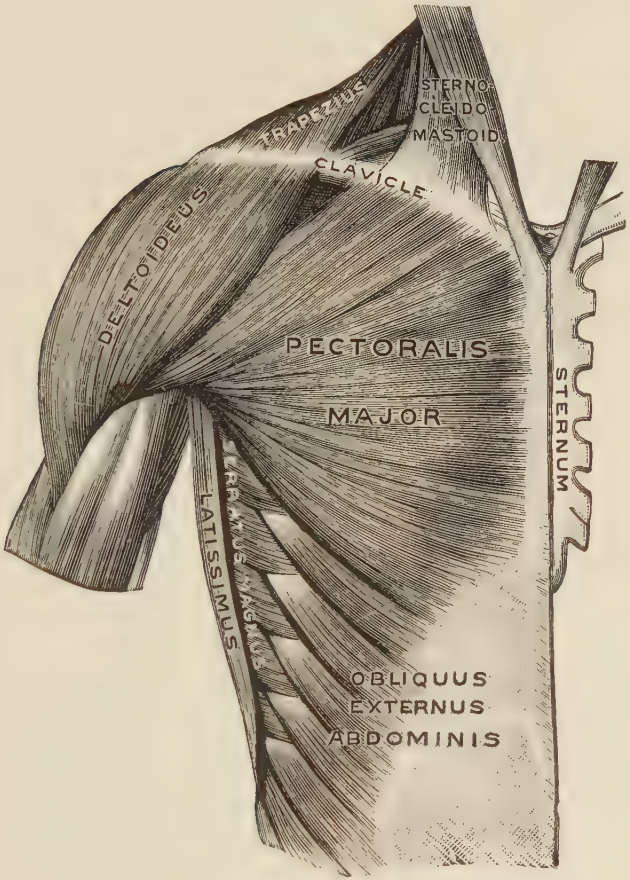


FIG. 127.—Front of chest and shoulder of right side, superficial muscles. (Testut.)

Supraspinatus. (Fig. 128.)

Location.—In the supraspinous fossa, covered by the trapezius.

Origin.—Inner two-thirds of supraspinous fossa.

Insertion.—The uppermost facet on the greater tuberosity of the humerus.

Nerve Supply.—The suprascapular.
Action.—Abducts the arm.

Pectoralis Major. (Fig. 127.)

Location.—Covers the front wall of the chest.
Origin.—The inner half of the anterior border of the clavicle.
The anterior surface of the sternum.
The cartilages of the upper six ribs.

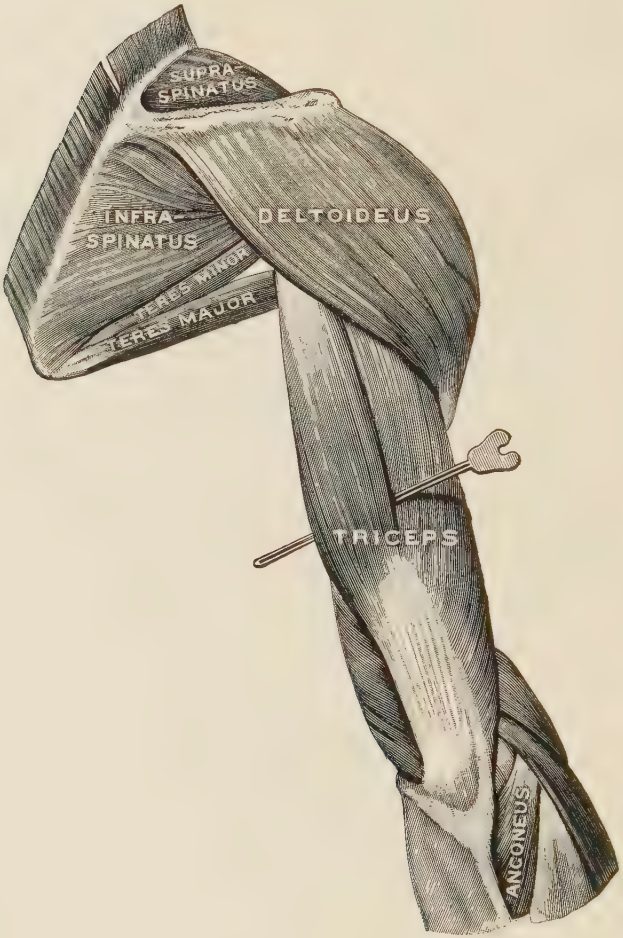


FIG. 128.—Muscles on the dorsum of the right shoulder and arm. (Testut.)

Insertion.—The outer lip of the bicipital groove of the humerus.
Nerve Supply.—Internal and external anterior thoracic.
Action.—Sternal portion helps to flex the arm. All portions draw the arm across the chest.

Coracobrachialis. (Figs. 129, 130.)

Location.—On the inner side of the upper part of the arm.

Origin.—The coracoid process of the scapula.

Insertion.—The middle of the inner border of the humerus.

Nerve Supply.—The musculocutaneous.

Action.—Flexion and adduction of the arm.

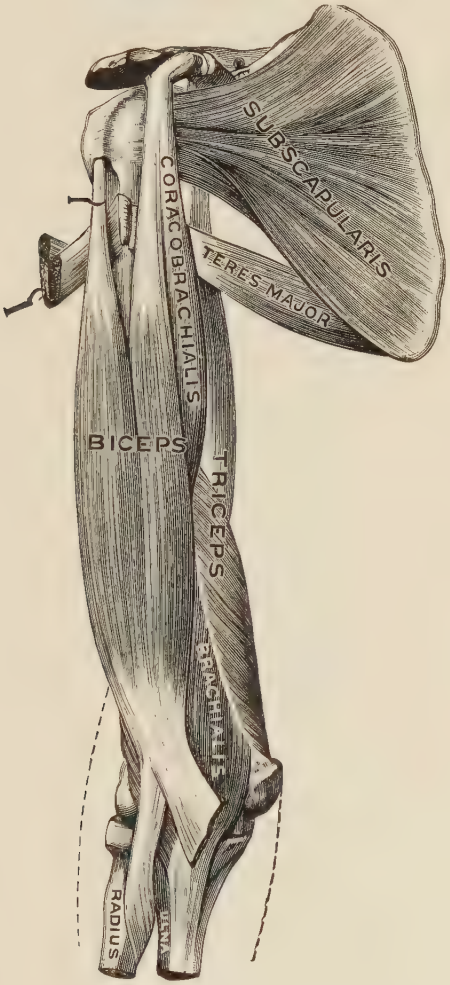


FIG. 129.—Muscles of the front of the right shoulder and arm. (Testut.)

Latissimus.—(O. T. latissimus dorsi). (Fig. 123.)

Location.—The lower part of the back and the axilla.

Origin.—Spines of six lower thoracic, all the lumbar and sacral spines. The lumbar fascia; the outer lip of the iliac crest, hind part. The three or four lower ribs, and the lower angle of the scapula.

Insertion.—The inner lip and floor of the bicipital groove of the humerus.

Nerve Supply.—Long subscapular.

Action.—Extension, adduction and inward rotation of the arm.

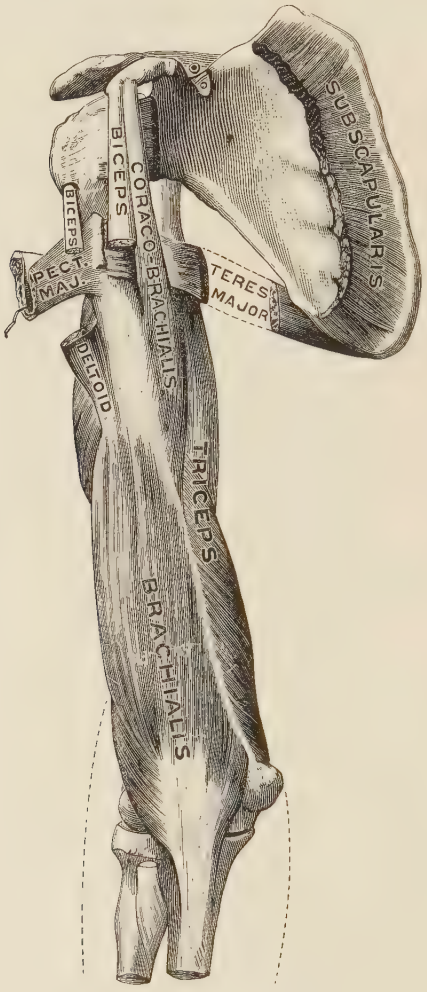


FIG. 130.—Muscles of the right arm, front view, the biceps having been removed. (Testut.)

Teres Major. (Fig. 124.)

Location.—In the posterior wall of the axilla.

Origin.—The dorsal surface of the axillary border of the scapula, lower half.

Insertion.—The inner lip of the bicipital groove of the humerus.

Nerve Supply.—Lower subscapular.

Action.—Helps the latissimus in extension, adduction and inward rotation of the arm.

Infraspinatus. (Fig. 124.)

Location.—On the back of the scapula, partly covered by the trapezius.

Origin.—Infraspinous fossa, inner two-thirds.

Insertion.—Middle facet on the greater tuberosity of the humerus.

Nerve Supply.—Suprascapular.

Action.—Rotates the arm outward.

Teres Minor. (Fig. 124.)

Location.—In the posterior wall of the axilla.

Origin.—Dorsal surface of axillary border of the scapula, upper half.

Insertion.—The lowermost facet on the greater tuberosity of the humerus.

Nerve Supply.—Circumflex.

Action.—Rotates the arm outward.

Subscapularis. (Fig. 125.)

Location.—The under surface of the scapula, next the chest wall.

Origin.—The ventral surface of the scapula, in the subscapular fossa.

Insertion.—The lesser tuberosity of the humerus.

Nerve Supply.—Upper and lower subscapular.

Action.—Rotation inward of the humerus.

THE MUSCLES MOVING THE FOREARM.

Flexors.	*Extensors.*
Biceps flexor cubiti	Triceps extensor cubiti
Brachialis	Anconeus
Brachio-radialis	

Biceps Flexor Cubiti. (Fig. 129.)

Location.—On the front of the arm, superficial.

Origin.—Long head, the upper border of the glenoid fossa. Short head, the coracoid process of the scapula.

Insertion.—The bicipital tuberosity of the radius.

Nerve Supply.—The musculocutaneous.

Action.—Flexes the forearm. The long head acts to flex the arm at the shoulder-joint. If the hand is pronated, the biceps supinates it. If the forearm is in supination, the biceps flexes it more easily.

Brachialis.—(O. T. brachialis anticus or anterior). (Fig. 130.)
Location.—The lower front of the arm, deeply placed.
Origin.—The lower half of the ventral surface of the arm, embracing the insertion of the deltoideus.

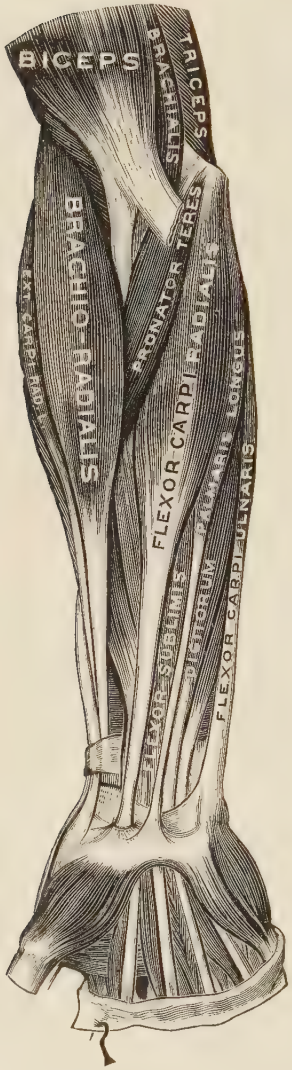


FIG. 131.—Superficial muscles of front of right forearm. (Testut.)

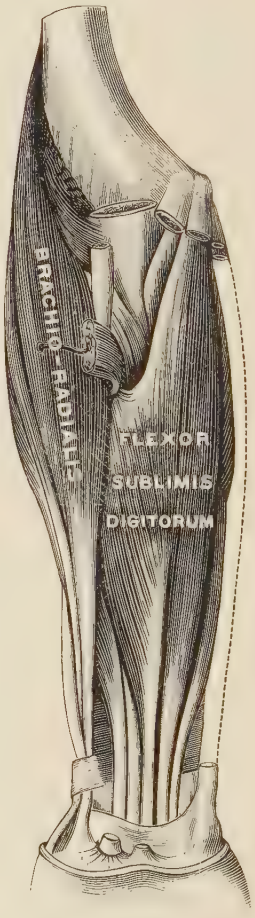


FIG. 132.—Flexor sublimis digitorum of right side. (Testut.)

Insertion.—The coronoid process of the ulna.
Nerve Supply.—Musculocutaneous, and to some degree, the musculospiral.
Action.—Flexes the forearm.

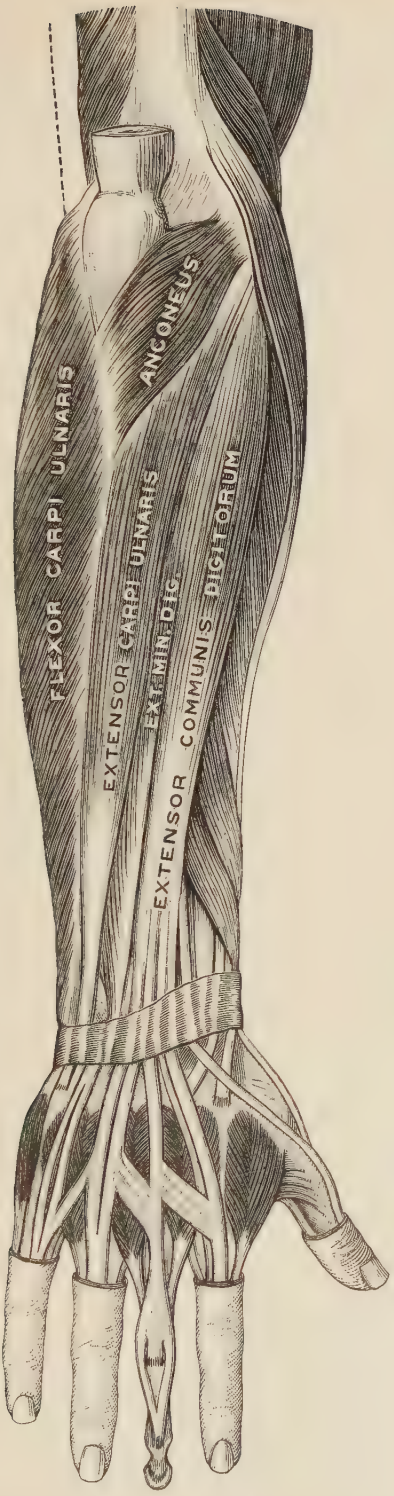


FIG. 133.—Muscles in the dorsum of the right forearm and hand. (Testut.)

Brachio-radialis.—(O. T. supinator longus). (Figs. 131, 132.)

Location.—The outer side of the forearm, superficial.

Origin.—Upper two-thirds of the external supracondylar ridge of the humerus.

Insertion.—The styloid process of the radius.

Nerve Supply.—Musculospiral.

Action.—Flexion of the forearm, especially in the position midway between pronation and supination.

Triceps Extensor Cubiti. (Fig. 128.)

Location.—On the back of the arm.

Origin.—Long head, the lower border of the glenoid fossa.

Inner head, the posterior surface of the humerus, below the musculospiral groove.

Outer head, the posterior surface of the humerus, above the musculospiral groove.

Insertion.—The back of the upper part of the olecranon process of the ulna.

Nerve Supply.—Musculospiral.

Action.—Extends the forearm. The long head extends the arm, acting with the latissimus.

Anconeus. (Figs. 128, 133.)

Location.—Back and outer side of the elbow-joint.

Origin.—The external condyle of the humerus.

Insertion.—Outer side of olecranon process and upper dorsal surface of ulna.

Nerve Supply.—Musculospiral.

Action.—A helper of the triceps in extending the forearm.

THE MUSCLES MOVING THE OUTER PART OF THE FOREARM.

Pronators.	*Supinator.*
Pronator teres	Supinator
Pronator quadratus	

Pronator Teres.—(O. T. pronator radii teres). (Fig. 131.)

Location.—Crosses over the front of the forearm, from within, outward.

Origin.—The inner condyle of the humerus.

Insertion.—The middle of the outer surface of the shaft of the radius.

Nerve Supply.—The median.

Action.—Pronation of the hand, and if that is prevented, flexion of the forearm.

Pronator Quadratus. (Fig. 134.)

Location.—Deep in the lower part of the front of the forearm.

Origin.—The lower fourth of the anterior surface of the ulna.

Insertion.—The lower fourth of the anterior surface of the radius.

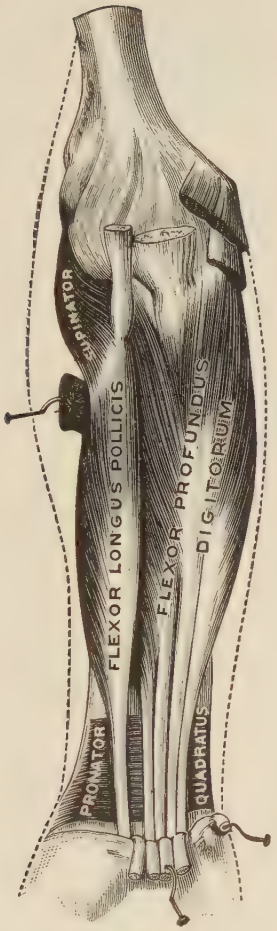


Fig. 134.—Muscles in the right forearm, the deepest layer. (Testut.)

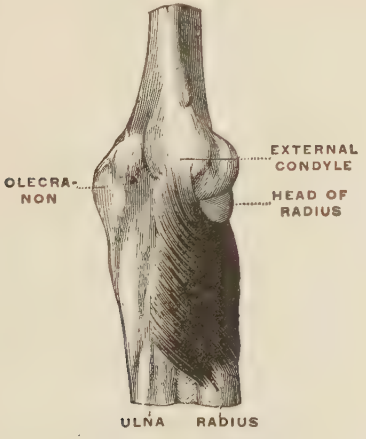


Fig. 135.—Supinator of right side. (Testut.)

Nerve Supply.—Anterior interosseous branch of the median.

Action.—Pronates the hand, turning the radius over the ulna.

Supinator.—(O. T. supinator brevis). (Fig. 135.)

Location.—Deep in the upper third of the outer part of the forearm.

Origin.—The external condyle of the humerus; the triangular area below the lesser sigmoid cavity of the ulna.

Insertion.—The back of the neck of the radius, and the posterior, outer surface of the same above the oblique line.

Nerve Supply.—Posterior interosseous division of the musculospiral.

Action.—Supinates the forearm, assisting the brachio-radialis, and serving as a supplementary ligament to the elbow-joint.

THE MUSCLES MOVING THE WHOLE HAND.

Flexors.	*Extensors.*
Flexor carpi radialis	Extensor carpi radialis longus
(Flexor) palmaris longus	Extensor carpi radialis brevis
Flexor carpi ulnaris	Extensor carpi ulnaris

The *extensor* muscles of the forearm and the *supinator* may be remembered as coming from the *external* condyle of the humerus or just above it. The flexor and pronator muscles come from the internal condyle, and are associated in action. Note the greater ease in piano playing, of running from the little finger to the thumb, than the reverse.

The movements at the wrist, besides flexion and extension are adduction and abduction, which are performed by the combined action of a flexor and extensor, on the ulnar and radial sides respectively.

Flexor Carpi Radialis. (Fig. 131.)

Location.—Superficial on the front of the forearm, crossing diagonally.

Origin.—Inner condyle of the humerus.

Insertion.—The base of the second metacarpal bone, on its palmar aspect.

Nerve Supply.—The median.

Action.—Flexion on radial side and pronation of hand. Helps the radial extensor to abduct the hand.

Palmaris Longus. (Fig. 131.)—A very small muscle, with a long tendon, coming from the internal condyle to the palmar fascia, which it makes tense. Does a little toward flexion. This muscle is quite frequently lacking.

Flexor Carpi Ulnaris. (Figs. 131, 133.)

Location.—On the front and inner aspect of the forearm.

Fig. 136.—Muscles in radial region of right forearm, and deep muscles in its dorsum. (Testut.)

Origin.—Inner condyle of the humerus.

Inner side of the olecranon process and the common aponeurosis on the dorsal border of the ulna, from which proceeds the extensor carpi ulnaris and the flexor profundus digitorum.

Insertion.—The pisiform, unciform and the base of the fifth metacarpal on the palmar aspect.

Nerve Supply.—Ulnar.

Action.—Flexes the hand on the ulnar side. Helps the ulnar extensor to adduct the hand.

Extensor Carpi Radialis Longus. (Fig. 136.)

Location.—On the outer border of the forearm.

Origin.—The lower part of the external supracondylar ridge of the humerus.

Insertion.—The base of the metacarpal of the first finger, posteriorly.

Nerve Supply.—Musculospiral.

Action.—Extends the hand on radial side.

Extensor Carpi Radialis Brevis. (Fig. 136.)

Location.—The outer part of the forearm, posteriorly.

Origin.—The external condyle of the humerus.

Insertion.—The base of the metacarpal of the second finger, posteriorly.

Nerve Supply.—Posterior interosseous branch of the musculospiral.

Action.—Extends the hand.

Extensor Carpi Ulnaris. (Fig. 133.)

Location.—On the ulnar side of the back of the forearm.

Origin.—External condyle of the humerus and posterior border of the ulna.

Insertion.—Base of the fifth metacarpal bone, on its posterior aspect.

Nerve Supply.—Posterior interosseous branch of the musculospiral.

Action.—Extends the hand on the ulnar side, and with the ulnar flexor, adducts the hand.

Note that the "carpi" muscles are inserted into the metacarpal bones but move the wrist-joint.

Note that all the extensor muscles are supplied by the musculospiral nerve.

THE MUSCLES MOVING THE FINGERS.

Flexors.	*Extensors.*
Flexor sublimis digitorum	Extensor communis digitorum
Flexor profundus digitorum	Extensor minimi digiti
*Flexor ossis metacarpi minimi digiti	Extensor indicis

*Flexor brevis minimi digiti
*Lumbricales

* These muscles are situated entirely in the hand.

Flexor Sublimis Digitorum. (Fig. 132.)

Location.—On the front of the forearm and the palm of the hand.

Origin.—The internal condyle of the humerus.
The coronoid process of the ulna, and the oblique line of the radius.

Insertion.—The sides of the base of the second phalanx of the four fingers. Above the wrist, the tendon divides into four parts, which pass under the annular ligament, through the palm of the hand, and on to the base of the second phalanx of each finger, where the tendons divide, going to each side of the bone, and leaving a slit through which the tendon of the deep flexor has to pass to get to the base of the third phalanx.

Nerve Supply.—The median.

Action.—Flexes the second phalanx of each of the fingers. Continuing to contract, it flexes secondarily, the first phalanx.

Flexor Profundus Digitorum. (Figs. 134 and 137.)

Location.—Deep in the front of the forearm, next the bone, and in the hand.

Origin.—The upper three-fourths of the ventral surface of the ulna.
The adjacent interosseous membrane.
The posterior border of the ulna, in common with the extensor carpi ulnaris and the flexor carpi ulnaris.

FIG. 137.—Tendon of flexor profundus perforating tendon of flexor sublimis. (Testut.)

Insertion.—The base of the third phalanx of the four fingers. Above the wrist the tendon divides into four slips, which pass into the hand, under those of the superficial flexor, and go up through the slit in the latter tendon to the distal phalanx.

Nerve Supply.—Ulnar and anterior interosseous branch of the median.

Action.—Flexes the third phalanx of the four fingers.

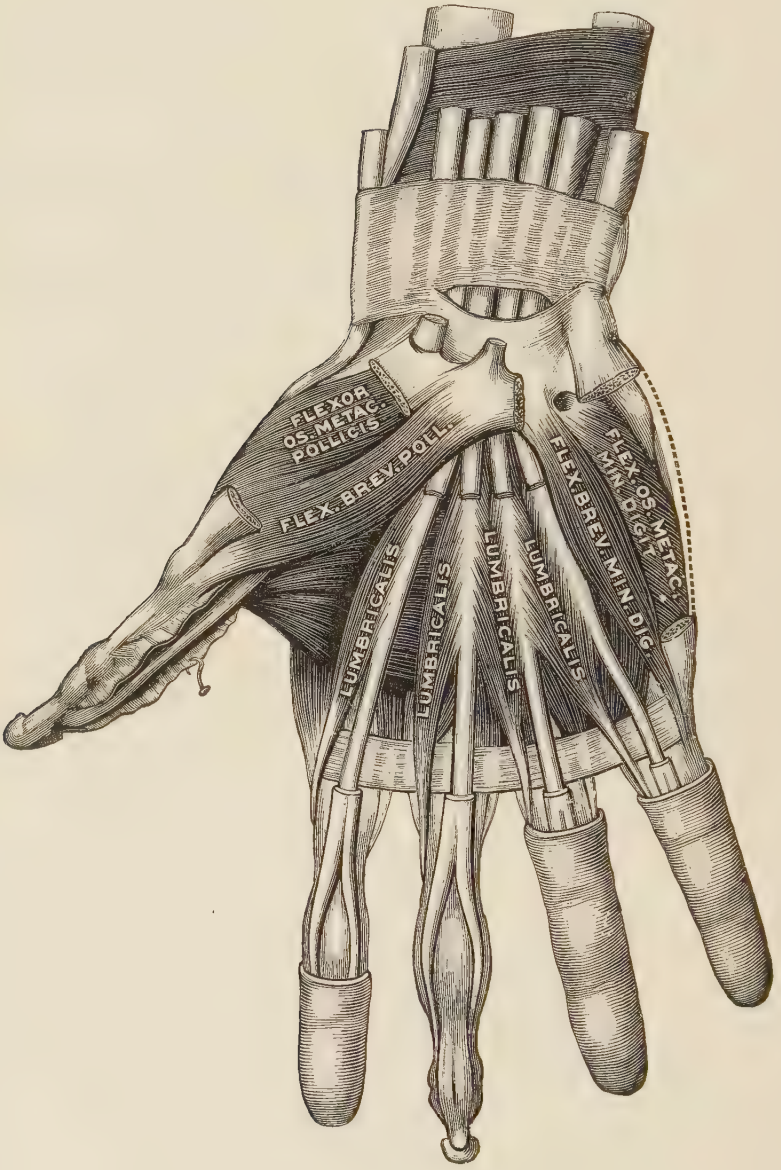


FIG. 138.—Muscles of the right palm. The abductors of the thumb and little finger have been removed. (Testut.)

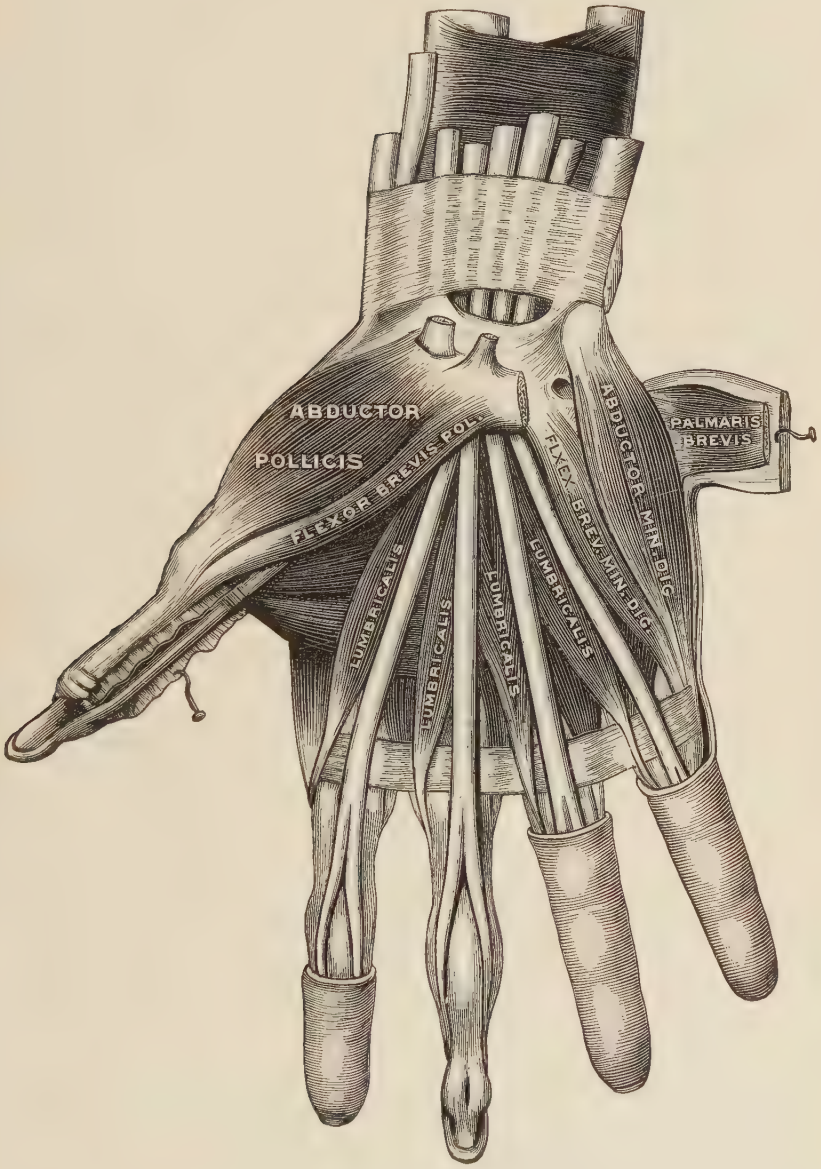


FIG. 139.—Muscles of the right palm. The palmaris brevis is reflected to the ulnar side. (Testut.)

Flexor Ossis Metacarpi Minimi Digiti. (Fig. 138) (O. T. Opponens minimi digiti.)—A small muscle deep in the hypothenar eminence, whose action draws the ulnar side of the hand outward, deepening the palm. It originates in the wrist and passes to the palmar side of the little finger metacarpal.

Flexor Brevis Minimi Digiti. (Fig. 138.)

Location.—In the palm of the hand, on the ulnar side, subcutaneously.

Origin.—Unciform process of the unciform bone and the annular ligament.

Insertion.—Base of the first phalanx of the little finger.

Nerve Supply.—Ulnar.

Action.—Flexes the first phalanx of the little finger.

Lumbricales. (Figs. 138, 139.)—Four small muscles pass from the tendons of the flexor profundus digitorum to those of the extensor communis digitorum. They are small, and so-called from their resemblance to earth worms. They flex the first phalanx of the fingers, and extend the second and third.

Extensor Communis Digitorum. (Fig. 133.)

Location.—On the back of the forearm and hand, superficial.

Origin.—The external condyle of the humerus.

Insertion.—The base of the second and third phalanges of each finger. Above the wrist, the tendon divides into four slips, which pass under the annular ligament, and then to the fingers. Each slip divides into three parts, the middle one attaching to the base of the second phalanx and the other two uniting to be attached to the base of the third phalanx of the fingers. The name "communis" refers to the fact that the tendinous attachment is to the two phalanges by a common tendon.

Nerve Supply.—Posterior interosseous branch of the musculospiral.

Action.—Extends the second and third phalanges of the fingers.

Extensor Minimi Digiti. (Fig. 133.)

Location.—In the back of the forearm and hand.

Origin.—External condyle of the humerus.

Insertion.—Second and third phalanges of the little finger.

Nerve Supply.—Posterior interosseous branch of the musculospiral.

Action.—Extends the second and third phalanges of the little finger.

Extensor Indicis. (Fig. 136.)

Location.—In back of forearm and hand.

Origin.—Lower part of the dorsal surface of the ulna and interosseous membrane.

Insertion.—The first tendon of the extensor communis digitorum.

Nerve Supply.—Posterior interosseous branch of the musculospiral.

Action.—Independent extension of the first finger, and slight adduction.

Abductors and Adductors of the Fingers. (Figs. 139, 140, 141.)—The fingers are abducted from the line passing through the second finger by four small muscles, the *interossei dorsales*. These originate from the contiguous sides of the five metacarpal bones, and the tendons are inserted on the first phalanges so that the first and second pull the first and second fingers from the central line. The

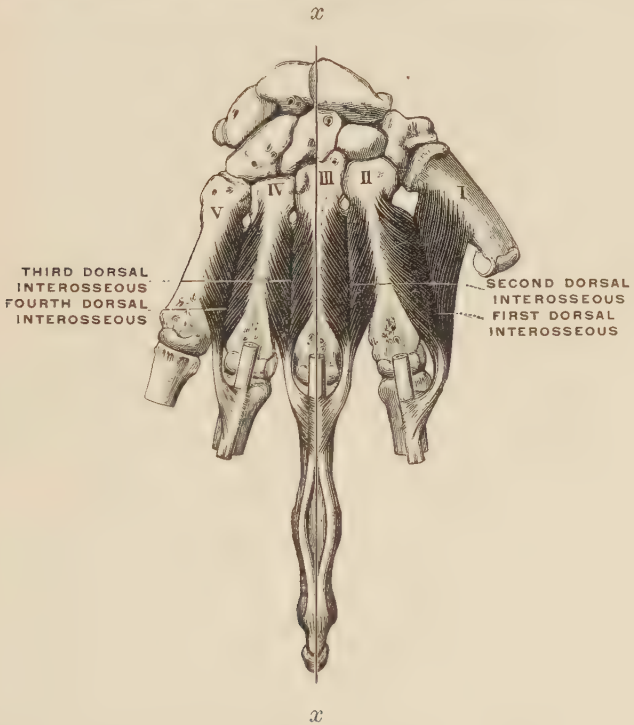


FIG. 140.—Interossei dorsales of right hand. The line $x\ x$ is that from which abduction is made. (Testut.)

third and fourth pull the second and third fingers from the central line. When the second tendon pulls the second finger toward the thumb side, it is adducted by the tendon attached on the ulnar side of this finger, and a similar condition results when the third tendon pulls the second finger toward the ulnar side. The second and third interossei dorsales muscles therefore act as abductors and adductors.

The *interossei palmares*, coming from the second, fourth and fifth metacarpal bones, are inserted into the bases of the corresponding

fingers, and adduct them toward the line passing through the middle of the second finger.

The little finger has a special abductor, on the palmar surface, coming from the pisiform bone to the base of the first phalanx of the little finger. These muscles are all supplied by the ulnar nerve.

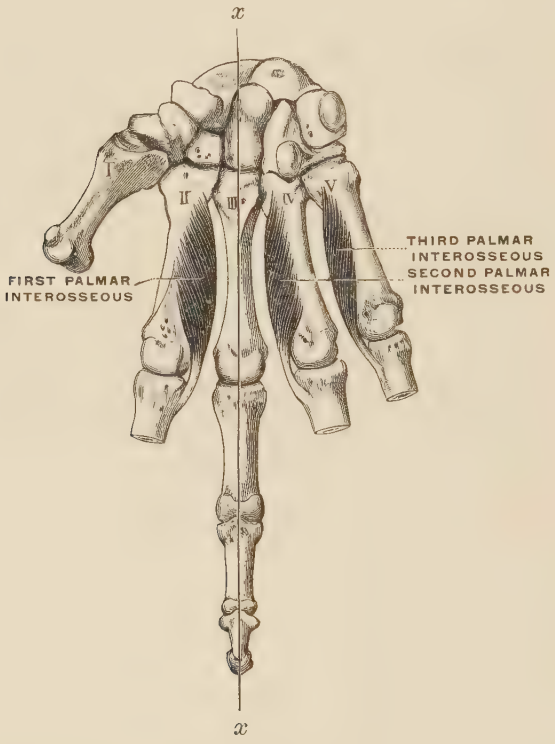


FIG. 141.—Interossei palmares of right hand. The line $x\ x$ is that to which adduction is made. (Testut.)

THE MUSCLES MOVING THE THUMB AND ITS METARCARPAL BONE.

Flexors.	*Extensors.*
*Flexor ossis metacarpi pollicis	Extensor ossis metacarpi pollicis
*Flexor brevis pollicis	Extensor brevis pollicis
Flexor longus pollicis	Extensor longus pollicis
Abductor.	*Adductor.*
*Abductor pollicis	*Adductor pollicis

* Entirely in the hand.

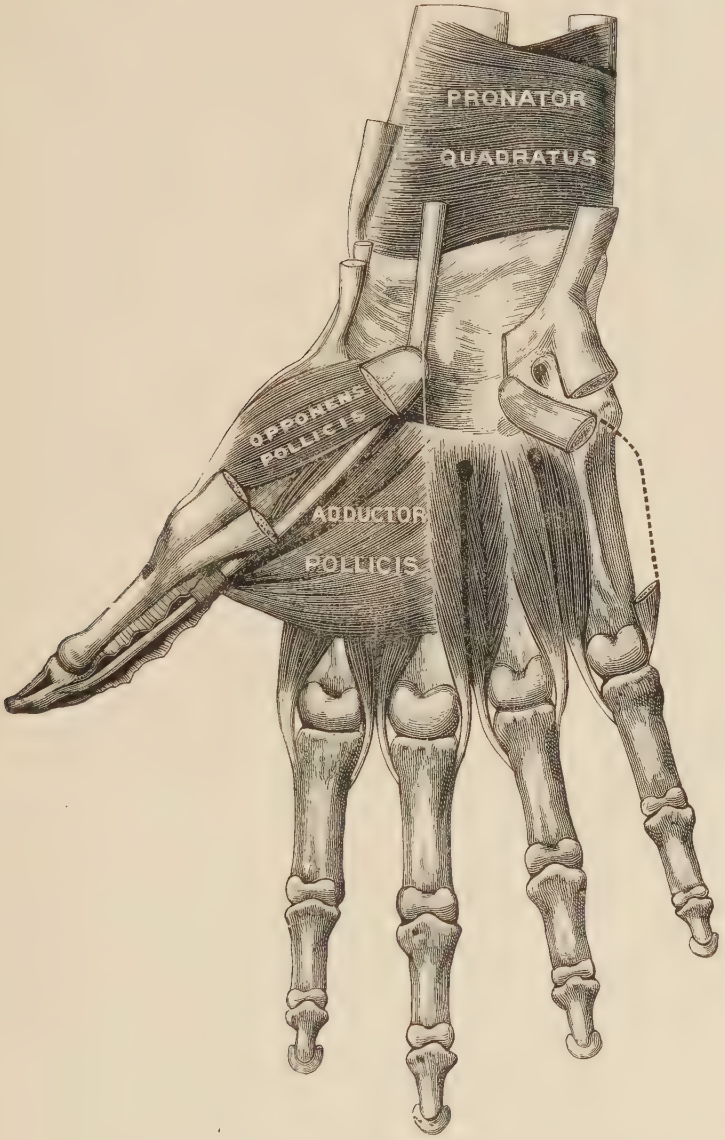


FIG. 142.—Adductor pollicis, flexor ossis metacarpi pollicis and pronator quadratus. (Testut.)

Flexor Ossis Metacarpi Pollicis.—(O. T. Opponens pollicis.) (Figs. 138, 142.)

Location.—Deep in the thenar eminence. (Thenar eminence, the ball of the thumb.)

Origin.—Trapezium and annular ligament, on the palmar aspect.

Insertion.—Shaft of the first metacarpal bone, on the front of the radial side.

Nerve Supply.—Median.

Action.—Flexes and rotates the first metacarpal inward.

Flexor Brevis Pollicis. (Fig. 138.)

Location.—Deep in the ball of the thumb.

Origin.—Trapezium and annular ligament on the radial side, palmar aspect. Upper part of the first metacarpal on the ulnar side.

Insertion.—First part, outer side of the base of the first phalanx of the thumb, with the abductor pollicis.

Second part, inner side of the base of the first phalanx of the thumb, with the adductor pollicis.

With each of these tendons there is a small sesamoid bone.

Nerve Supply.—The first part, the median; second part, the ulnar.

Action.—Flexes the first phalanx of the thumb.

Flexor Longus Pollicis. (Fig. 134.)

Location.—Front part of forearm and palmar aspect of the thumb.

Origin.—Oblique line of radius, and middle two-thirds of shaft. Interosseous membrane adjoining.

Insertion.—Base of second phalanx of the thumb, palmar aspect.

Nerve Supply.—Anterior interosseous branch of the median.

Action.—Flexes the second phalanx of the thumb.

Extensor Ossis Metacarpi Pollicis.—(O. T. Abductor longus pollicis.) (Fig. 136.)

Location.—Deep in the lower part of the back of the forearm.

Origin.—The posterior shaft of the radius and ulna, with membrane between.

Insertion.—Base of the first metacarpal bone, dorsally.

Nerve Supply.—Posterior interosseous branch of the musculospiral.

Action.—Extension and abduction of the first metacarpal bone.

Extensor Brevis Pollicis.—(O. T. Extensor primi internodii pollicis.) (Fig. 136.)

Location.—Deep in the lower part of the back of the forearm.

Origin.—Middle of the posterior shaft of the radius, and adjacent membrane.

Insertion.—Base of the first phalanx of the thumb, on dorsal aspect.

Nerve Supply.—Posterior interosseous branch of the musculospiral.

Action.—Extends the first phalanx of the thumb.

Extensor Longus Pollicis.—(O. T. Extensor secundi internodii pollicis.) (Fig. 136.)

Location.—Deep in the lower part of the back of the forearm.

Origin.—Middle of the posterior shaft of the ulna and adjacent membrane.

Insertion.—The base of the second phalanx of the thumb, dorsal aspect.

Nerve Supply.—Posterior interosseous branch of the musculospiral.

Action.—Extends the second phalanx of the thumb.

Abductor Pollicis. (Fig. 139.)

Location.—Superficial on the ball of the thumb.

Origin.—Trapezium, scaphoid and annular ligament, palmar aspect.

Insertion.—Base of the first phalanx of the thumb, on the radial side.

Nerve Supply.—Median.

Action.—Abducts the thumb.

Adductor Pollicis. (Fig. 142.)

Location.—Deep in the radial side of the palm.

Origin.—Os magnum, bases of second and third metacarpal bones, and annular ligament. Lower two-thirds of the third metacarpal shaft, palmar aspect.

Insertion.—Inner side of the base of the first phalanx of the thumb.

Nerve Supply.—Ulnar.

Action.—Adduction and flexion of first phalanx of thumb.

THE MUSCLES OF THE LOWER EXTREMITY.

Movements of the Thigh.—As the hip-joint is a ball-and-socket joint, all kinds of movement are possible here, as in the shoulder-joint, though there is less freedom. Forward movement of the thigh is *flexion;* backward movement is *extension;* sideways outward is *abduction;* sideways inward is *adduction; circumduction* is the combination of these and *rotation* takes place as in the arm.

Movements of the Leg.—At the knee-joint, *flexion* is movement backward; *extension* is forward; and the small amount of rotation at the end of extension and beginning of flexion is respectively outward and inward.

Movements of the Foot.—At the hinge of the ankle, movement upward is *flexion;* movement downward is *extension.* The movement of *inversion,* turning the sole toward the middle line, and its

reverse of *eversion* takes place at the medio-tarsal and astragalo-calcaneal joints.

Movements of the Toes.—*Flexion* of the toes is movement downward; *extension* is movement upward, while *adduction* and *abduction* take place at the metatarso-phalangeal joints, toward and from the middle line of the second toe.

THE MUSCLES MOVING THE THIGH.

Flexors.	*Extensor.*
Psoas magnus	Gluteus maximus
Iliacus	
Abductors.	*Adductors.*
Tensor fasciæ latæ	Adductor magnus
Gluteus medius	Adductor longus
Gluteus minimus	Adductor brevis
	Adductor gracilis
	Pectineus
Internal rotators.	*Outward rotators.*
Tensor fasciæ latæ	Obturator externus
Gluteus medius	Obturator internus
Gluteus minimus	Pyriformis
	Gemellus superior
	Gemellus inferior
	Quadratus femoris

Psoas Magnus or Major.—(Fig. 143.)

Location.—Back part of the abdomen and upper part of thigh.

Origin.—Bodies of the last thoracic and all the lumbar vertebræ and the cartilages between, with the transverse processes.

Insertion.—The lesser trochanter of the femur.

Nerve Supply.—Second and third lumbar.

Action.—Flexion of the thigh and outward rotation.

Iliacus. (Fig. 143.)

Location.—In the hind wall of the abdomen and upper part of the thigh.

Origin.—The iliac fossa, and the ala of the sacrum.

Insertion.—The lesser trochanter, along with the psoas magnus.

Nerve Supply.—Anterior crural.

Action.—With the psoas, it flexes and rotates the thigh outwardly. These two muscles are often referred to as one, the psoas magnus.

Gluteus Maximus. (Fig. 144.)

Location.—Forming most of the buttock.

Origin.—Outer lip of the iliac crest (posterior fourth).
Dorsal surface of the ilium between the crest and superior gluteal line; two lower segments of the sacrum and the coccyx.
The aponeurosis of the erector spinæ.

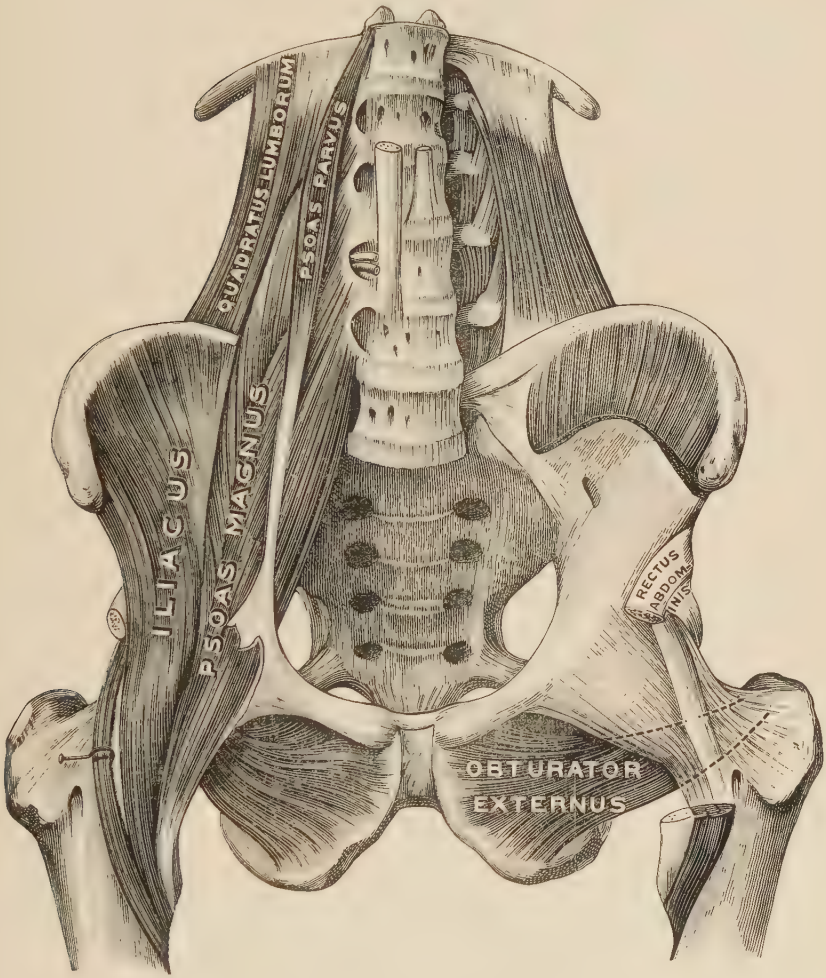


FIG. 143.—Psoas, iliacus and obturator externus muscles. (Testut.)

Insertion.—Gluteal ridge of femur and fascia lata.
Nerve Supply.—Inferior gluteal.
Action.—Extension of the thigh and outward rotation.

Tensor Fasciæ Latæ.—(O. T. Tensor vaginæ femoris.) (Fig. 145.)
Location.—Upper and outer aspect of the thigh, anteriorly.

Origin.—Just below the crest of the ilium, back of the anterior-superior spine.

Insertion.—Into the fascia lata, below the great trochanter.

Nerve Supply.—Superior gluteal.

Action.—Abduction and inward rotation of the thigh; tensing the fascia lata.

Gluteus Medius. (Fig. 146.)

Location.—Outer part of the hip, forming part of the buttock.

Origin.—The space between the superior and middle gluteal ridges of the ilium.

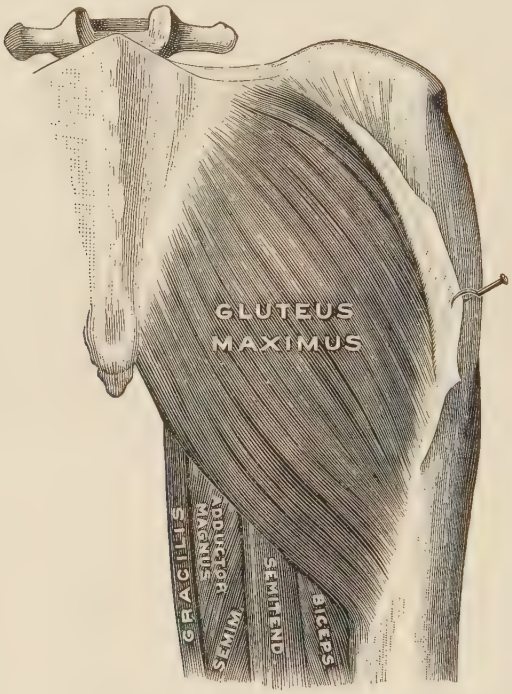


Fig. 144.—Gluteus maximus of right side. (Testut.)

Insertion.—Outer surface of the great trochanter.

Nerve Supply.—Superior gluteal.

Action.—Abduction of the thigh when it is extended, and inward rotation of the thigh when it is flexed.

Gluteus Minimus.

Location.—The outer part of the hip, under the medius.

Origin.—Between the middle and inferior gluteal ridges, on the dorsum of the ilium.

Insertion.—The front of the great trochanter.

Nerve Supply.—Superior gluteal.

Action.—Abduction of the extended, inward rotation of the flexed thigh.

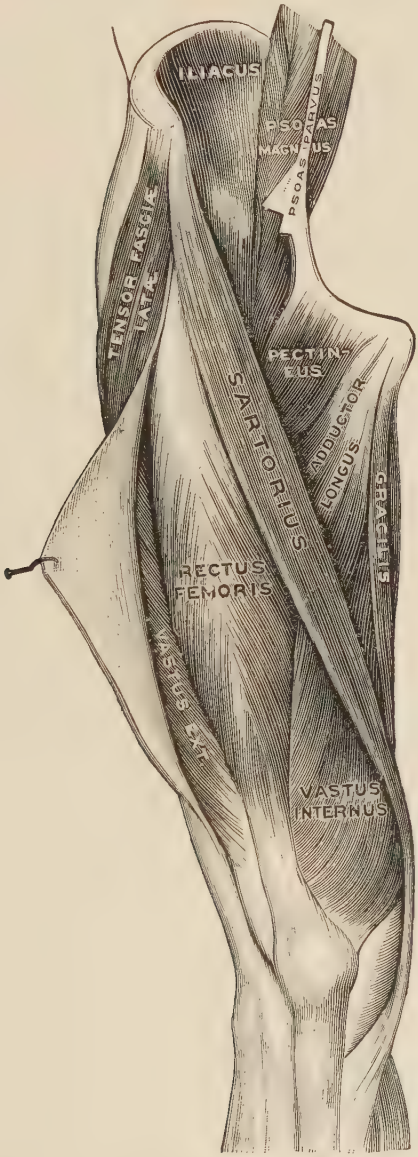


FIG. 145.—Superficial muscles in front part of the right thigh. (Testut.)

Adductor Magnus. (Figs. 147, 148.)

Location.—The full length of the inner side of the thigh.

Origin.—Rami of pubis and ischium, and the ischial tuberosity.
Insertion.—Gluteal ridge, inner lip of linea aspera, internal condylar ridge and adductor tubercle of femur.
Nerve Supply.—Obturator and great sciatic.
Action.—Adduction of thigh and outward rotation. The fibers coming from the ischial tuberosity extend the thigh upon the hip.

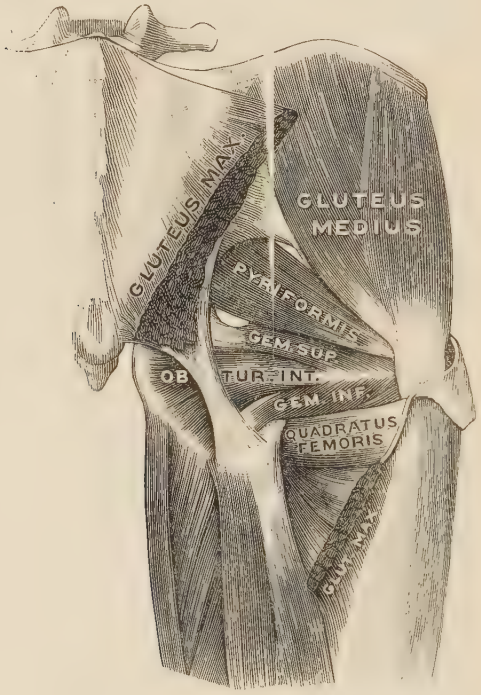


FIG. 146.—Muscles of right hip, viewed from behind, the gluteus maximus having been cut away. (Testut.)

Adductor Longus. (Fig. 149.)
Location.—Inner side of the thigh.
Origin.—Body of the pubic bone near the angle.
Insertion.—The middle third of the linea aspera, inner lip.
Nerve Supply.—Obturator.
Action.—Adducts, flexes and outwardly rotates the thigh.

Adductor Brevis. (Fig. 147.)
Location.—Inner and upper side of the thigh.
Origin.—Body and descending ramus of the os pubis.
Insertion.—Upper part of the linea aspera.
Nerve Supply.—Obturator.
Action.—Adducts, flexes and outwardly rotates the thigh.

Adductor Gracilis. (Fig. 149.)

Location.—Inner side of the thigh and back of knee.

Origin.—Descending ramus and symphysis of the os pubis.

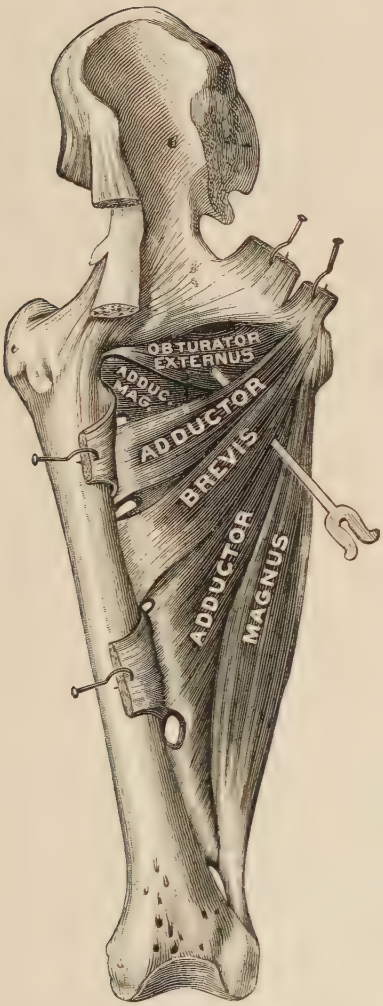


FIG. 147.—Adductores magnus and brevis of right side. (Testut.)

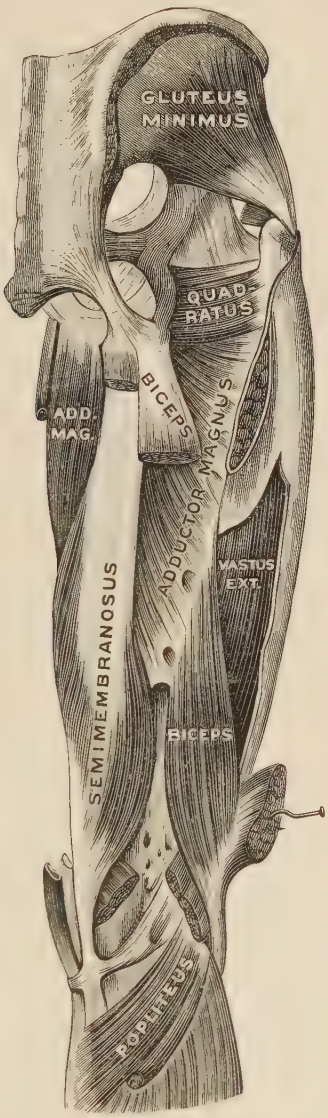


FIG. 148.—Muscles in deep portion of dorsum of right thigh, the semitendinosus and most of the biceps having been removed. (Testut.)

Insertion.—Upper part of the inner aspect of the tibia, near the tubercle.

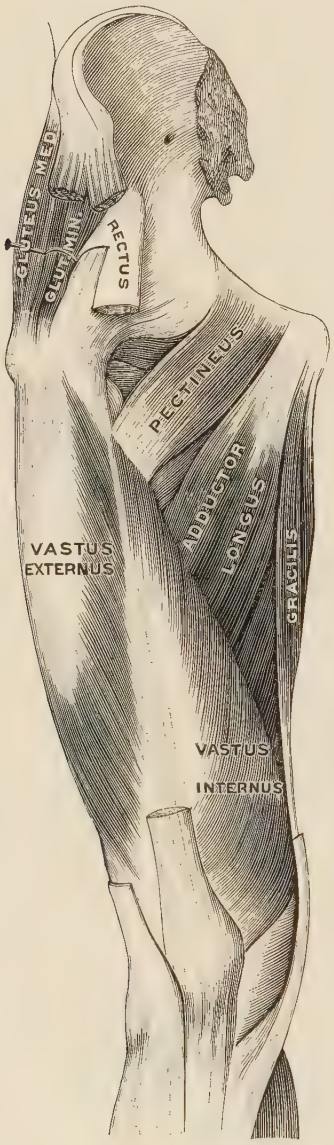


FIG. 149.—Muscles in the right thigh, viewed from in front, after removal of the rectus and sartorius. (Testut.)

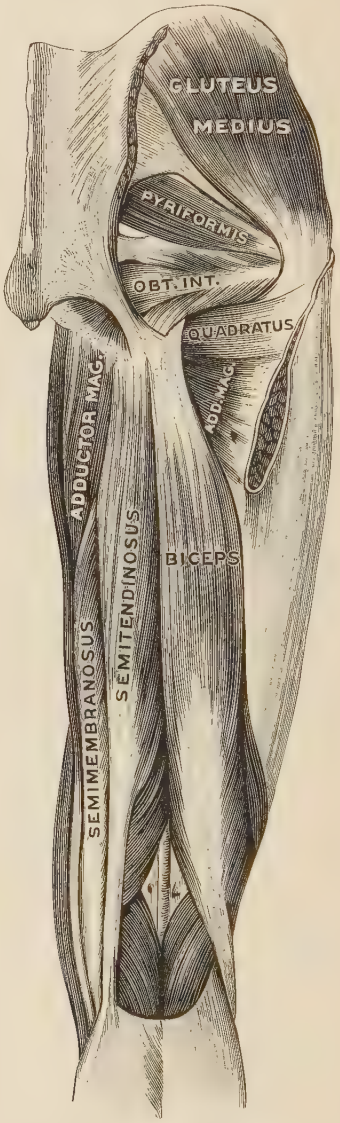


FIG. 150.—Muscles in the dorsum of the right thigh. (Testut.)

Nerve Supply.—Obturator.

Action.—Flexes the leg, and inwardly rotates it.

Pectineus. (Fig. 149.)

Location.—Between the front of the pelvis and the back of the thigh.

Origin.—Iliopectineal line of ilium, and surface in front of it.

Insertion.—Upper half of the pectineal line behind the small trochanter.

Nerve Supply.—Anterior crural, and sometimes the obturator.

Action.—Adducts, flexes and slightly rotates the thigh outwardly.

Obturator Externus. (Fig. 147.)

Location.—Outer surface of the pelvis.

Origin.—The outer surface of the obturator membrane, the contiguous bony surface and the rami of the os pubis and ischium.

Insertion.—Bottom of the digital fossa.

Nerve Supply.—Obturator.

Action.—Adducts and rotates thigh outwardly.

Obturator Internus. (Fig. 150.)

Location.—On the inner wall of the pelvis.

Origin.—Inner surface of the obturator membrane; margin of foramen; and space between the foramen, iliopectineal line and great sacro-sciatic foramen.

Insertion.—Inner surface of great trochanter, toward the front.

Nerve Supply.—Branch from the sacral plexus.

Action.—Outward rotation, when thigh extended; abducts the thigh when flexed.

Pyriformis. (Fig. 146.)

Location.—On the posterior wall of the true pelvis.

Origin.—Posterior border of ilium below the inferior spine; ventral surface of the second, third and fourth segments of the sacrum.

Insertion.—Upper border of great trochanter, anteriorly.

Nerve Supply.—Branch from the sacral plexus.

Action.—Outward rotation when thigh is extended; abducts when flexed.

Gemellus Superior and Inferior. (Fig. 146.)—Two small muscles, one above, the other below the obturator internus, and assisting in its work with similar insertion.

Quadratus Femoris. (Fig. 146.)

Location.—Back of the hip-joint.

Origin.—Outer border of the ischial tuberosity.

Insertion.—Quadrate line on back of femur.

Nerve Supply.—Branch from the sacral plexus.

Action.—Adducts and outwardly rotates thigh.

THE MUSCLES MOVING THE LEG.

Flexors.	*Extensors.*
*Sartorius	Quadriceps extensor cruris, comprising
*Biceps flexor cruris	**Rectus femoris
*Semitendinosus	Vastus lateralis
*Semimembranosus	Vastus medialis
Popliteus	Vastus intermedius

* These four flexors of the leg, cross the hip-joint as well, and act to extend the thigh, if flexion of the leg is prevented or is completed.

** This muscle passing over both the hip- and knee-joints, acts as a flexor of the thigh, when the leg is fully extended or the knee held in a flexed position so it cannot extend.

Sartorius. (Fig. 145.)

Location.—On the front of the thigh crossing over to the inner side of the knee.

Origin.—Anterior-superior spinous process of the ilium, and just below.

Insertion.—The upper part of the inner aspect of the tibia, near the tubercle.

Nerve Supply.—Anterior crural.

Action.—Flexes the leg and thigh with synchronous abduction of the thigh; then outward rotation.

Biceps Flexor Cruris. (Fig. 150.)

Location.—In the back of the thigh and knee-joint.

Origin.—Long head, the tuberosity of the ischium.
Short head, the lower part of the linea aspera and upper two-thirds of the external condylar ridge.

Insertion.—The head of the fibula.

Nerve Supply.—Great sciatic.

Action.—Flexes the leg, with external rotation. Extends the thigh.

Semitendinosus. (Fig. 150.)

Location.—Inner side of the back of the thigh.

Origin.—Tuberosity of the ischium.

Insertion.—Upper part of the inner aspect of the tibia, near the tubercle.

Nerve Supply.—Great sciatic.

Action.—Flexes the leg, then rotates it inward. Extends the thigh.

Semimembranosus. (Figs. 148, 150.)

Location.—Inner side of the back of the thigh.

Origin.—Tuberosity of the ischium.

Insertion.—A groove on the inner and posterior aspect of the inner tuberosity of the tibia.

Nerve Supply.—Great sciatic.

Action.—Flexes leg, than rotates it inward. Extension of the thigh.

NOTE.—The tendons of the gracilis, semitendinosus and semimembranosus, form the "inner hamstrings." The tendon of the biceps flexor cruris forms the "outer hamstring."

Popliteus. (Fig. 148.)

Location.—Back of the knee, close to the joint.

Origin.—The outer side of the external condyle of the femur.

Insertion.—Above the oblique line of the tibia, on a triangular area.

Nerve Supply.—Internal popliteal branch of the great sciatic.

Action.—Flexes and rotates leg inward.

The Quadriceps Femoris (Quadriceps extensor cruris) is a compound of four muscles, placed on the thigh and enveloping it, front and sides, leaving only part of the linea aspera uncovered. The insertion of the combination is through one large tendon, to the tubercle of the tibia. In this tendon is developed the sesamoid bone, the patella.

Rectus Femoris. (Fig. 145.)

Origin.—Anterior-inferior spine of the ilium and a reflected tendon from above the acetabulum.

Insertion.—The tubercle of the tibia.

Nerve Supply.—Anterior crural.

Action.—Extends the leg and flexes the thigh.

Vastus Lateralis.—(O. T. Vastus externus.) (Figs. 149 and 151.)

Location.—On the outer and back part of the thigh.

Origin.—Anterior intertrochanteric line; base of great trochanter; the gluteal ridge and the outer lip of the linea aspera.

Insertion.—The tubercle of the tibia.

Nerve Supply.—Anterior crural.

Action.—Extends the leg.

Vastus Medialis.—(O. T. Vastus internus.) (Figs. 149, 151.)

Location.—On the inner part of the thigh.

Origin.—Spiral line, inner lip of linea aspera, and internal supracondylar ridge.

Insertion.—The tubercle of the tibia.

Nerve Supply.—Anterior crural.

Action.—Extends the leg.

Vastus Intermedius.—(O. T. Crureus.) (Fig. 151.)

Location.—Deep on the front of the thigh.

Origin.—The upper two-thirds of the shaft of the femur, anteriorly.

Insertion.—The tubercle of the tibia.

Nerve Supply.—Anterior crural.

Action.—Extends the leg.

A few muscular fibers arise from the lower part of the femur, and are inserted into the synovial membrane of the knee-joint. This is the *musculus articularis genu,* or muscle of the knee-joint. Its function is to pull the synovial membrane out of the way of being pinched in extension of the knee.

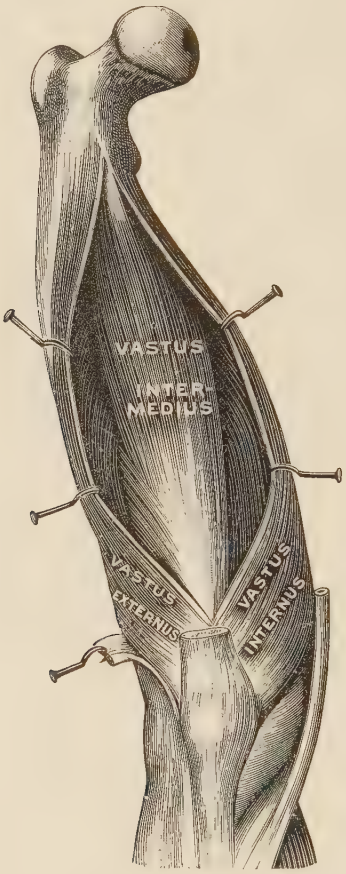


FIG. 151.—Vastus intermedius of right side. (Testut.)

THE MUSCLES MOVING THE FOOT.

Flexors.	*Extensors.*
Tibialis anterior	Tibialis posterior on inner side
Peroneus tertius	Gastrocnemius, Soleus, Plantaris — in the center
	Peroneus longus, Peroneus brevis — on outer side

Tibialis Anterior.—(O. T. Tibialis anticus.) (Fig. 152.)

Location.—On the front and outer side of the tibia.

Origin.—Outer tuberosity and upper two-thirds of the external surface of the tibia and adjacent interosseous membrane.

Insertion.—Inner surface of the internal cuneiform bone, and the base of the first metatarsal.

Nerve Supply.—Anterior tibial branch of the great sciatic.

Action.—Flexes the foot upon the leg, raises the *inner* border and adducts the front of the foot. Or flexes and inverts foot.

Peroneus Tertius. (Fig. 152.)

Location.—Lower front part of the leg.

Origin.—Lower fourth of the anterior surface of the fibula and adjacent membrane.

Insertion.—Base of the fifth metatarsal, upper surface.

Nerve Supply.—Anterior tibial branch of the great sciatic.

Action.—Flexes foot, raises *outer* border and abducts front or inversion.

Tibialis Posterior.—(O. T. Tibialis posticus.) (Fig. 153.)

Location.—Deep in the back of the leg, and crossing the sole of the foot.

Origin.—The lateral half of the middle third of the posterior surface of the tibia. Upper two-thirds of the shaft of the fibula and the interosseous membrane adjacent.

Insertion.—Tuberosity of the scaphoid, with off-shoots to the three cuneiform, the cuboid, the bases of the second, third and fourth metatarsals, and to the sustentaculum tali of the calcaneum. (Thereby getting a grip on the entire sole, after passing back of the inner malleolus. Very important in maintaining the arch of the foot.)

Nerve Supply.—Posterior tibial branch of the great sciatic.

Action.—Extends the foot on the leg; raises the *inner* border and adducts the front of the foot. Or extends and inverts foot.

Gastrocnemius. (Fig. 154.)

Location.—Superficial in the calf of the leg.

Origin.—By two heads, from the inner and outer condyles of the femur, and just above.

Insertion.—The back of the calcaneum, by the tendo Achillis.

Nerve Supply.—Internal popliteal branch of the great sciatic.

Action.—Extends the foot upon the leg. Flexes the leg on the thigh.

Soleus. (Fig. 155.)

Location.—Deep in the calf of the leg.

Origin.—Head and upper third of the posterior surface of the fibula. Oblique line and inner border of tibia to the middle of the shaft.

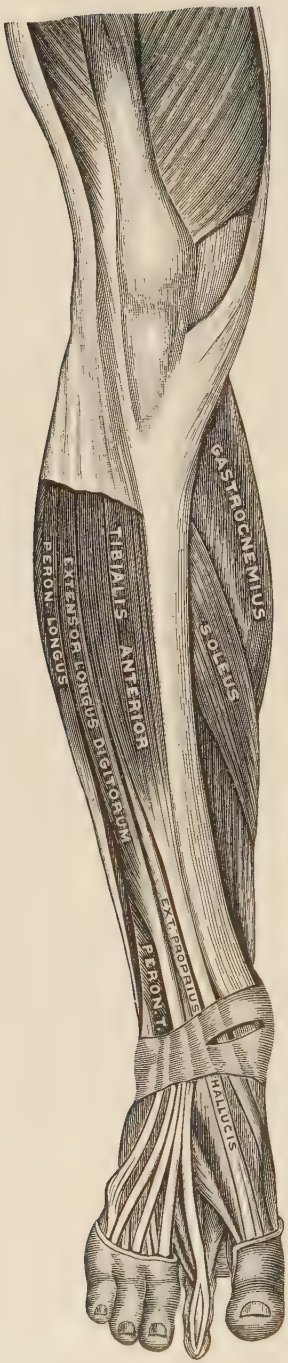


Fig. 152.—Muscles in the right leg, viewed from in front. (Testut.)

Fig. 153.—Muscles in the deep layer of the dorsum of the right leg. (Testut.)

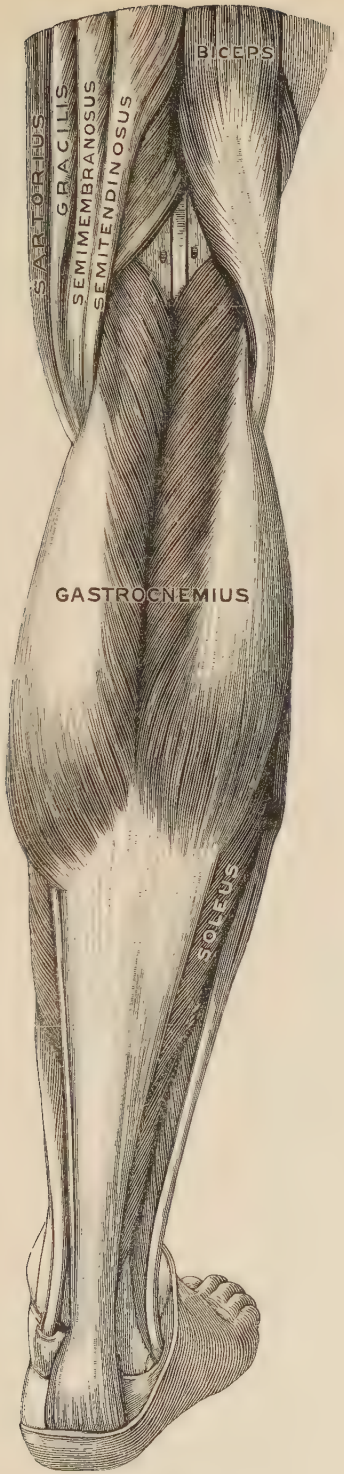


FIG. 154.—Gastrocnemius of right side. (Testut.)

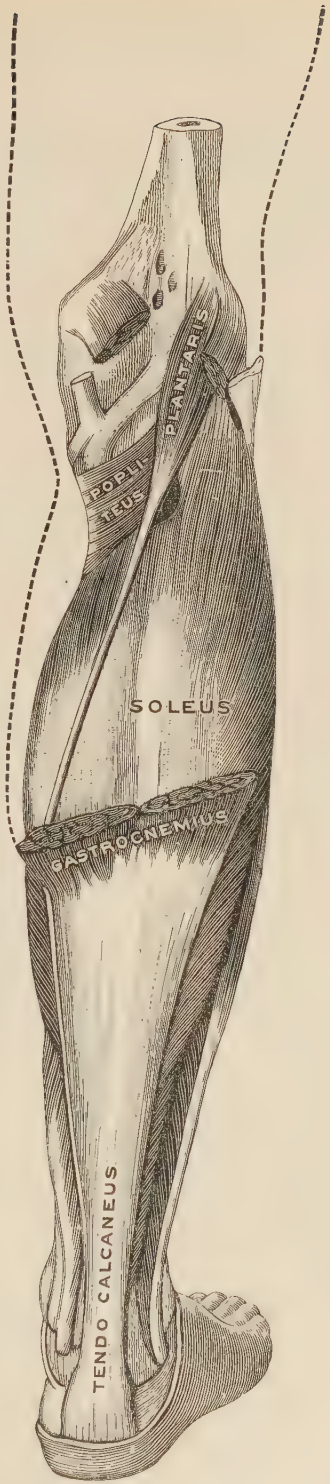


FIG. 155.—Soleus and plantaris of right side. (Testut.)

Insertion.—The back of the calcaneum, by the tendo Achillis.

Nerve Supply. —Internal popliteal and posterior tibial branches of the great sciatic.

Action.—Extends foot on leg. By extension of foot, the weight of the body is raised.

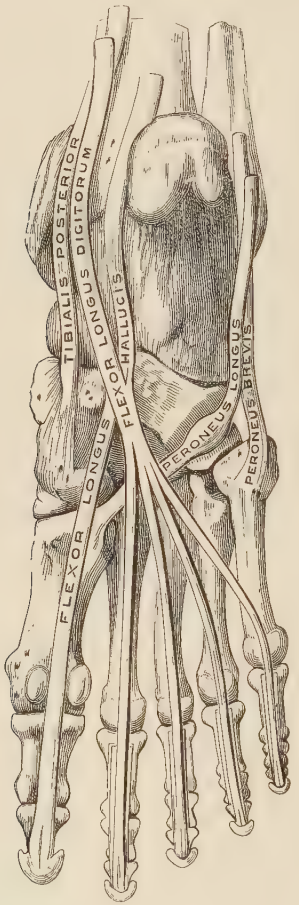


FIG. 156.—Tendons in the right sole. (Testut.)

Plantaris.—A small muscle, arising from above the external condyle of the femur, and inserted with the above two. Slight action in extending foot and flexing leg. (Fig. 155.)

Peroneus Longus. (Figs. 153 and 156.)

Location.—On the outer side of the leg.

Origin.—Head and upper two-thirds of outer surface of the fibula; the outer tuberosity of the tibia.

Insertion.—Under surface of inner cuneiform and base of first metatarsal. Passing back of the outer malleolus, the tendon of insertion, goes forward on the outer side of the calcaneum, and through the groove in the cuboid, diagonally forward and inward across the sole.

Nerve Supply.—Branch of the external popliteal division of the great sciatic.

Action.—Extends the foot, raises the *outer* side and abducts the front. Or extension and eversion, with depression of the great toe.

Peroneus Brevis. (Fig. 156.)

Location.—Lower and outer part of the leg.

Origin.—The lower two-thirds of the outer surface of the fibula.

Insertion.—Outer side of the fifth metatarsal, on its tuberosity.

Nerve Supply.—Branch of the external popliteal division of the great sciatic.

Action.—Extends foot, raises the *outer* side and abducts the front. Or eversion.

Note the combined action of the tibialis anterior and posterior in inverting the foot, with their antagonistic action at the ankle-joint; also, that the peroneal muscles combine in everting the foot, though the tertius opposes the other two in its action at the ankle-joint; and, as a group the tibial muscles oppose the peroneals at the mediotarsal joint.

THE MUSCLES MOVING THE TOES.

Flexors.	*Extensors.*
*Flexor longus hallucis	*Extensor proprius hallucis
Flexor brevis hallucis	*Extensor longus digitorum
*Flexor longus digitorum	Extensor brevis digitorum
Flexor accessorius	
Flexor brevis digitorum	
Flexor brevis minimi digiti	
Lumbricales	

* These muscles act on the toes but are in the leg.

Abductors.	*Adductors.*
Abductor hallucis	Adductor obliquus hallucis
Abductor minimi digiti	Adductor transversus hallucis
Interossei dorsales	Interossei plantares

Flexor Longus Hallucis. (Figs. 153, 156.)

Location.—Deep in the back of the leg and in the sole of the foot.

Origin.—Lower two-thirds of the posterior surface of the fibula, and adjacent membrane.

Insertion.—Under surface of the base of the second phalanx of the great toe. Tendon passes back of the inner malleolus and beneath the sustentaculum tali.

Nerve Supply.—Posterior tibial branch of the great sciatic.

Action.—Flexes last phalanx of the great toe. Extends foot at the ankle.

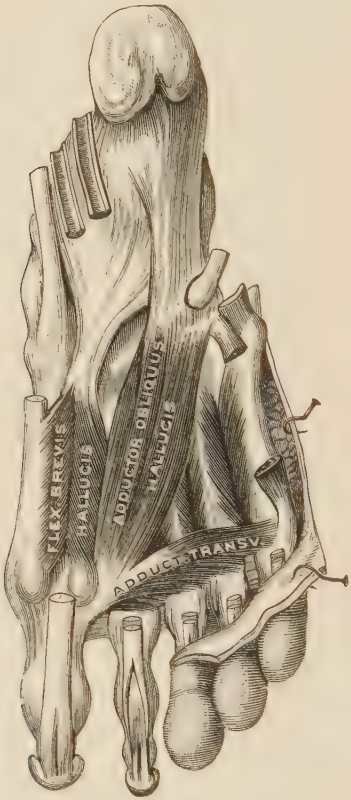


FIG. 157.—Muscles in the third layer of the right sole. The belly of the flexor brevis minimi digiti has been removed. (Testut.)

Flexor Brevis Hallucis. (Figs. 157, 158.)—Originates from the cuboid and the tendon of the tibialis posterior, passing by two tendons to the two sides of the base of the first phalanx of the great toe, in common with the abductor and adductor of same. Each tendon encloses a sesamoid bone, and in the middle is the tendon of the long flexor of the great toe. The action is to flex the great toe.

Flexor Longus Digitorum. (Figs. 153, 156.)

Location.—Deep in the back of the leg, and in the sole of the foot.

Origin.—Inner part of the posterior surface of the tibia, the middle two-fourths.

Insertion.—By four tendons to the base of the third phalanx of the four lesser toes. The tendon of the muscle passes behind the inner malleolus, forward in the sole, and divides into four slips just above the heads of the metatarsal bones, and has to go through the perforated slips of the brevis to get to the last phalanx.

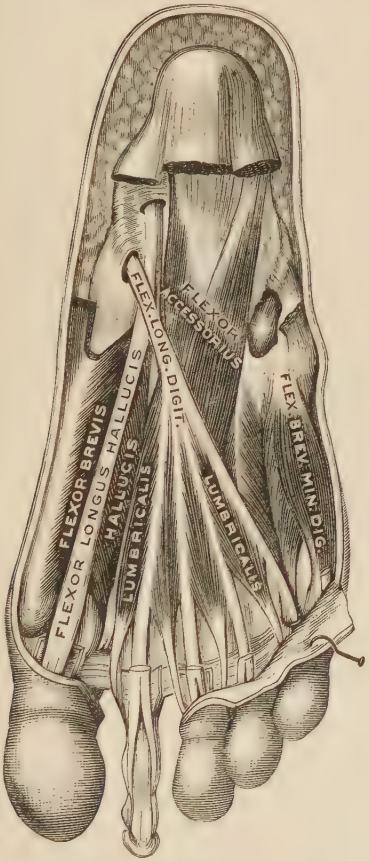


FIG. 158.—Flexor accessorius and lumbricales of right foot. (Testut.)

FIG. 159.—Muscles of the superficial layer of the right foot. (Testut.)

Nerve Supply.—Posterior tibial branch of the great sciatic.

Action.—Flexes the last phalanx of the four lesser toes. Extends the foot.

Flexor Accessorius. (Fig. 158.)—A muscle originating on the calcaneum, passing forward in the sole to the outer posterior border

and upper surface of the above tendon. It flexes the small toes and brings into line with the long axis of the foot, the line of action of the longus digitorum.

Flexor Brevis Digitorum. (Fig. 159.)

Location.—Sole of the foot.

Origin.—Front of the calcaneum.

Insertion.—By four tendons to the sides of the second phalanx of the four lesser toes.

FIG. 160.—Extensor brevis digitorum of right foot. (Testut.)

Nerve Supply. Internal plantar branch of the great sciatic.

Action.—Flexes second phalanx of the four lesser toes.

Flexor Brevis Minimi Digiti Pedis. (Fig. 158.)—A small muscle which flexes the first phalanx of the smallest toe.

Lumbricales. (Fig. 158.) Like the lumbricales of the hand, these muscles pass between the flexor and extensor tendons of the toes. They flex the first phalanx and extend the second and third phalanges of the four lesser toes.

Extensor Proprius Hallucis. (Fig. 152.)

Location.—In the front of the leg and the dorsum of the foot.

Origin.—Middle two-fourths of the fibula, anteriorly and adjacent membrane.

Insertion.—Base of the last phalanx of the great toe, on dorsum.

Nerve Supply.—Anterior tibial branch of the great sciatic.

Action.—Extends the great toe. Flexes the foot on the leg.

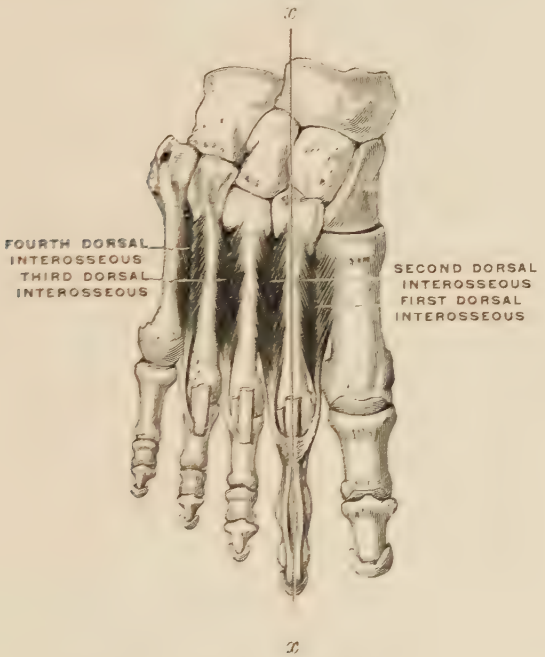


FIG. 161.—Interossei dorsales of right foot. The line *x x* is that from which abduction is made. (Testut.)

Extensor Longus Digitorum. (Fig. 152.)

Location.—In the front of the leg and dorsum of the foot.

Origin.—Outer tuberosity of the tibia; head and upper two-thirds of the fibula, anteriorly; and the adjacent interosseous membrane.

Insertion.—The tendon divides into four slips, which are inserted into both the second and third phalanges of the four lesser toes.

Nerve Supply.—Anterior tibial branch of the great sciatic.

Action.—Extends the four lesser toes. Flexes the foot at the ankle.

Extensor Brevis Digitorum.—A small muscle, entirely in the dorsum of the foot, which is inserted by four tendons into the first phalanx of the great toe, and to the extensor tendon of the longus for the next three toes. Helps to extend the toes.

Abductor Hallucis. (Fig. 159.)—Passing from the calcaneum forward, this is inserted into the inner side of the base of the first phalanx of the great toe, with the inner head of the flexor brevis hallucis. It flexes and abducts the great toe.

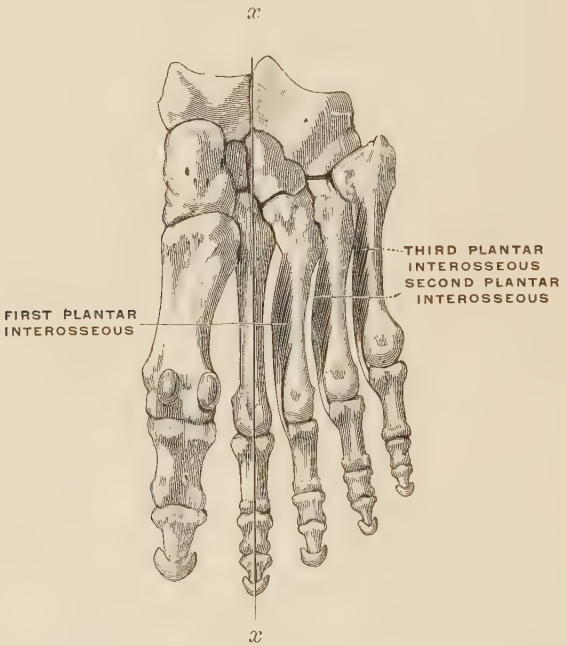


FIG. 162.—Interossei plantares of right foot. The line $x\ x$ is that to which adduction is made. (Testut.)

Abductor Minimi Digiti Pedis. (Figs. 159, 160.)—Passing from the calcaneum forward, this is inserted into the outer side of the little toe, first phalanx. It abducts the little toe.

Interossei Dorsales Pedis. (Fig. 161.)

Interossei Plantares. (Fig. 162.)—The interossei muscles of the foot serve as adductors and abductors of the toes, to and from the line passing through the second toe, in the same way as in the hand.

Two special adductors of the great toe, the oblique and transverse adductors, pass between the great toe and the little toe, helping to preserve the transverse arch of the foot. (Fig. 157.)

THE MUSCLES OF THE TRUNK.

The muscles of the trunk may be divided into three groups:
Those of the back, including some of the neck muscles.
Those of the abdomen.
Those of the thorax.

The muscles of the back compose five layers, none of which are entirely complete. In the first layer, are the *trapezius* and the *latissimus dorsi*. In the second layer are the *levator scapulæ* and the *rhomboidii major* and *minor*.

The Muscles in the Third Layer of the Back.

Serratus posterior superior and inferior.
Splenius capitis and cervicis.

Serratus Posterior Superior.—(O. T. Serratus posticus superior.) (Fig. 163.)

Location.—Upper part of the thorax.
Origin.—Lower part of the ligamentum nuchæ; spinous processes of the last cervical and two or three upper dorsal.
Insertion.—Second to the fifth ribs, beyond the angles.
Nerve Supply.—Second and third intercostals.
Action.—Raises the upper ribs. Helps to extend the spine, in reversed action. Probably acts in forced inspiration.

Serratus Posterior Inferior.—(O. T. Serratus posticus inferior.) (Fig. 124.)

Location.—Lower part of the back of the thorax.
Origin.—Spinous processes of the two lower dorsal and two upper lumbar vertebræ.
Nerve Supply.—Tenth and eleventh intercostal.
Action.—Draws down and backward the lower ribs, probably in forced inspiration.

Splenius Capitis.—(Fig. 163.)

Location.—The back of the neck, in front of the trapezius.
Origin.—Ligamentum nuchæ, in the region of third to seventh cervical, and from the spinous processes of the first two to five thoracic vertebræ.
Insertion.—Mastoid process of the temporal and adjacent part of the occipital bone.
Nerve Supply.—Second, third and fourth cervical nerves.
Action.—Inclines and rotates the head and neck toward the side on which muscle is placed. When both sides act, the head and neck are extended.

Splenius Cervicis.—(O. T. Splenius colli.) (Fig. 163.)

Location.—Lower part of the back of the neck.

Origin.—Spinous processes of the third to sixth cervical vertebræ.

Insertion.—Posterior tubercles of the first two or three cervical vertebræ.

Nerve Supply.—Second, third and fourth cervical.

Action.—Inclines and rotates the neck toward the side on which the muscle lies. When both act, the neck is extended.

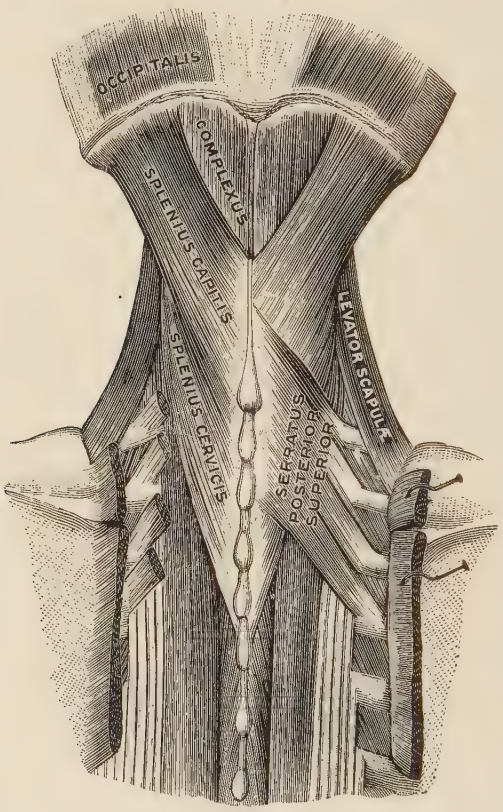


FIG. 163.—Muscles in the third layer of the back. (Testut.)

THE MUSCLES IN THE FOURTH LAYER OF THE BACK. (Figs. 164, 165, 166.)

The muscles in this layer comprise what is known as the *erector spinæ* group, extending from the lower end of the spine to the head. It originates as a tendinous sheet, covering the sacral region with the muscle mass filling the space between the iliac crest and the lowest ribs. This mass divides into three divisions, called the inner, outer and middle divisions, which climb the back by relays.

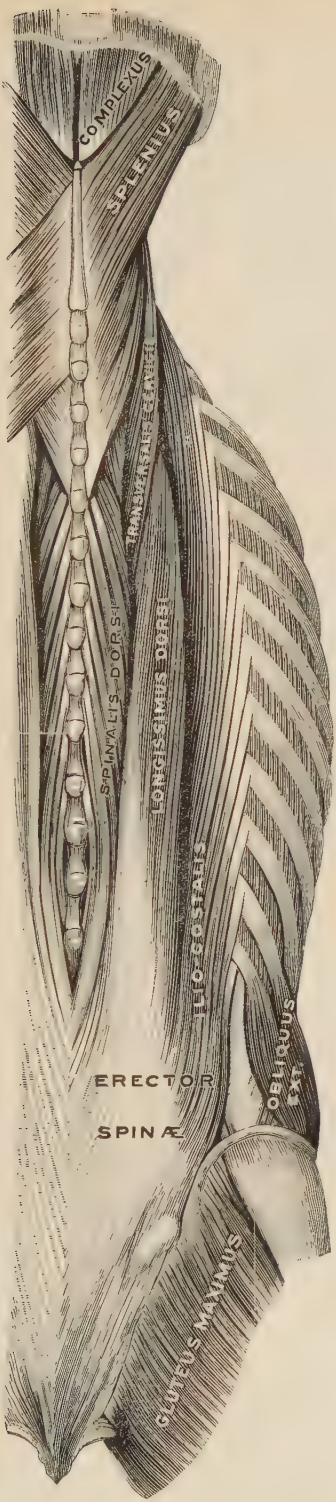


FIG. 164.—Erector spinæ, superficial view. (Testut).

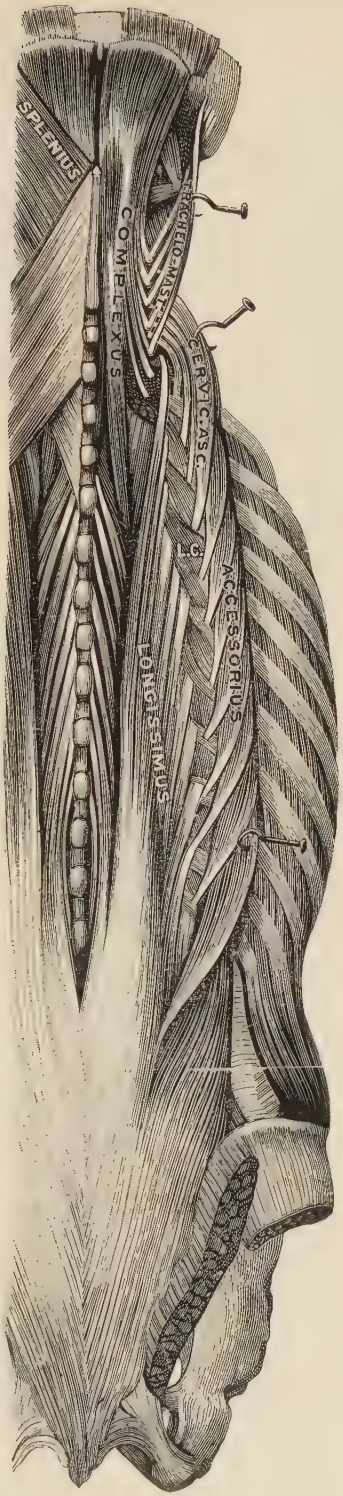
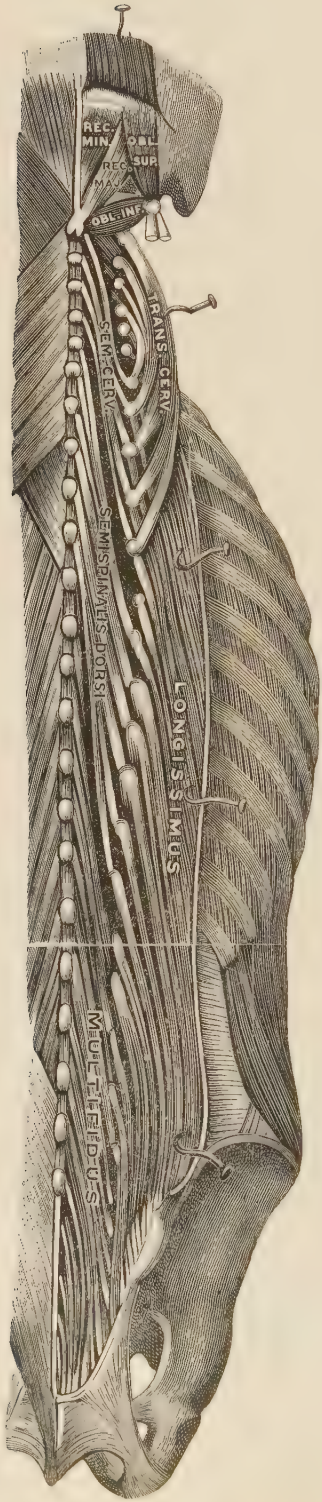


FIG. 165.—Erector spinæ. The outer series is pulled outward. (Testut.)



The inner division is called the *spinalis dorsi* (Fig. 164), and its fibers start from the muscular mass near the middle of the thorax, and are inserted into the spines of the upper thoracic vertebræ, going by steps three or four at a time.

The outer division goes from the twelfth rib to the lower part of the neck, while the middle division is carried all the way to the head. The outer division (Figs. 164, 166), begins as the *iliocostalis*, whose muscular slips start from the mass in the lumbar region, and climb up the ribs to the lower six or seven, near their angles. In close association with these, other slips pass upward from the six lower to the six upper ribs, as the *musculus accessorius ad iliocostalem*, or the accessory muscle of the iliocostalis.

The slips have now been carried to the upper margin of the thorax, and a new series of slips relays the erector spinæ from the five ribs between the third and seventh, to the transverse processes of the cervical vertebræ between the fourth and sixth. This is the *cervicalis ascendens*. The middle division, the longissimus dorsi (Figs. 164, 165, 166), sends slips up the back to the transverse processes of all the lumbar and thoracic vertebræ and to the ribs between the angles and tubercles. These slips vary in length according to the distance gone. (In studying the illustrations, Figs 165 and 166 notice that the muscle slips have been turned inside out by the hooks so as to show the individual attachments.) The longissimus is prolonged upward by the *transversalis cervicis* or *colli*. Slips arise from the transverse processes of from four to six upper thoracic vertebræ and are inserted into the transverse processes of the cervical vertebræ from the second to the sixth.

This division is further prolonged by the *trachelo-mastoideus*, which arising from the transverse processes of the

Fig. 166.—Erector spinæ. The middle series is pulled outward. (Testut.)

upper four to six thoracic vertebræ, and the articular processes of the lower three or four cervical vertebræ is carried through the neck to the mastoid process of the temporal bone.

The nerve supply of these small divisions comes from the contiguous spinal nerves.

While the erector spinæ as a whole is the length of the back, the subdivisions are not large nor long, and as the belly of the muscles is the contracting part, there is a succession of short pulls on the different segments of the spine, making the movements gradual, sustained and powerful. The direct action of the group is the erection or extension of the trunk, with the fixed points at the lower part of the back. If one side acts alone, lateral movement of the trunk to that side is produced. The contractual power of a muscle is measured by its cross-section, so the sum of the cross-sections of these many muscles is equal to one very large one, which would show great power by its size.

The Muscles in the Fifth Layer of the Back.

These lie in front of the fourth layer and consist of many small slips mostly arising from the transverse processes of the vertebræ, and going to the spinous processes of vertebræ four or five segments ahead.

The names of these are:

Complexus, or *Semispinalis capitis*. (Figs. 165, 166.)
Semispinalis cervicis.
Semispinalis dorsi.
Multifidus spinæ.
Rotatores spinæ.

The *complexus* is the largest muscle of the group, and arises from the transverse processes of the upper six or seven thoracic vertebræ and from the articular processes of the middle three or four cervical, and is inserted into the surface of the occiput between the superior and inferior curved lines.

Its action is to extend the head, but if only one side acts, it draws the head to the same side.

The *semispinalis cervicis* and *dorsi* pass from the transverse processes of the vertebræ to the spinous processes of those several segments above. They act to extend the neck and spine, but if one side acts alone, the spine is flexed to that side with rotation.

The *multifidus spinæ* consists of many small slips, which fill the hollow space on each side of the spinous processes, and as their arrangement is essentially the same as the others of this group, the action is the same as the above.

The *rotatores spinæ* act between the transverse processes of the thoracic vertebræ and the laminæ of the same. Their action is to

rotate the spine to the *opposite* side, extend and flex laterally. The nerves supplying these muscles are from the spinal cord in the neighborhood.

A group of small muscles, the *suboccipital*, are more important than their size warrants, as they are seemingly often contracted without the consciousness of a person, producing considerable nervous strain. However, they are under the control of the will.

Suboccipital Muscles. (Fig. 166.)

Rectus capitis posterior major.
Rectus capitis posterior minor.
Obliquus capitis inferior.
Obliquus capitis superior.

These four muscles are deeply placed under the overhang of the occiput, and pass from the axis and atlas to the occiput. Their actions are to extend the head and rotate it, directly or by rotating the atlas carrying the head.

The suboccipital nerve supplies these muscles, but their involuntary constant contraction interferes with the functioning of the sympathetic fibers in the region.

THE MUSCLES OF THE ABDOMEN.

Rectus abdominis	Obliquus internus abdominis
Pyramidalis	Transversalis abdominis
Obliquus externus abdominis	Quadratus lumborum

The abdominal cavity is covered in by these six muscles, which are arranged in three layers. In the male subject, it is usually possible to separate the layers and see distinct thickness in them. In the female subject, on the dissecting table, it is frequently difficult to distinguish the separate layers, because the entire covering is so thin on account of lack of development of the muscles.

Rectus Abdominis. (Fig. 167.)

Location.—In the front wall of the abdomen near the middle.
Origin.—The crest and symphysis of the os pubis.
Insertion.—The cartilages of the fifth, sixth and seventh ribs.
Nerve Supply.—Lower intercostal and iliohypogastric.
Action.—Flexes the spine, if one side is used; depresses the thorax; compresses the abdominal viscera; when thorax is fixed, it flexes the pelvis on the trunk.

Pyramidalis.—An adjunct to the rectus, not always present. It passes from the pubic ramus to the lower part of the *linea alba.* It draws down the linea alba in the middle line. Same nerve supply as the *rectus.*

Obliquus Externus Abdominis. (Fig. 168.)

Location.—Superficial in the lateral wall of the abdomen.

Origin.—By eight fleshy digitations from the eight lower ribs beyond the cartilages. First five interdigitate with the serratus magnus, the other three with the latissimus dorsi.

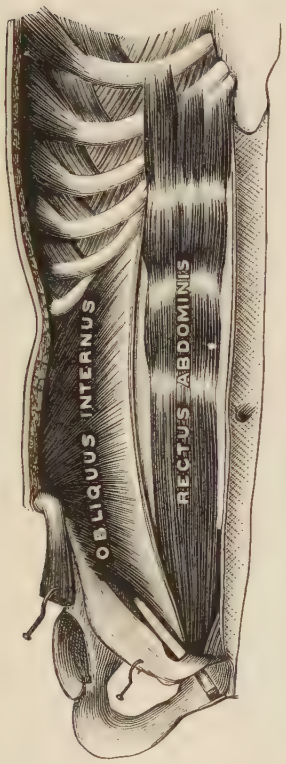


FIG. 167.—Rectus abdominis and obliquus internus of right side. (Testut.)

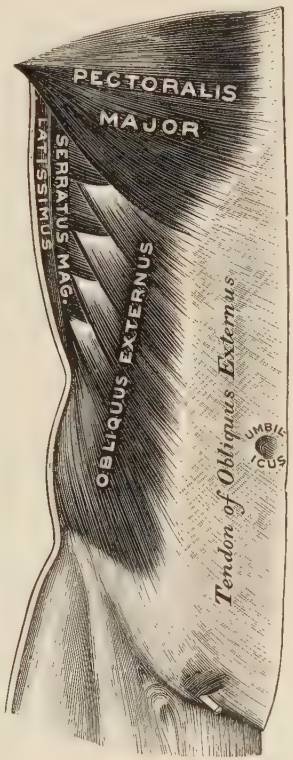


FIG. 168.—Obliquus externus abdominis of right side. (Testut.)

Insertion.—The anterior half of the outer lip of the crest of the ilium; Poupart's ligament; and the linea alba.

Nerve Supply.—Lower intercostals, ilioinguinal and iliohypogastric.

Action.—Compresses the abdominal viscera; depresses the thorax; flexes the spine; rotates the trunk to the opposite side, when only one side acts; with the thorax fixed, it flexes and rotates the pelvis to the same side.

Poupart's ligament is not a true ligament, but is the lower border of the obliquus externus abdominis between the anterior-superior

spine of the ilium and the pubic tubercle. The muscle is covered by fascia, which folds under and forms a shelf-like structure, to which other muscles are attached. This is also called the *inguinal ligament.*

The tendon of insertion of the obliquus externus, internus and the transversalis is a sheath of fibrous tissue, that is in layers. On the outer side is that from the externus which passes in front of the rectus, covering it, joined to the outer half of the internus aponeurosis, and interlacing with the fibers from the other side of the abdomen to form a dense fibrous band, the "white line" or linea

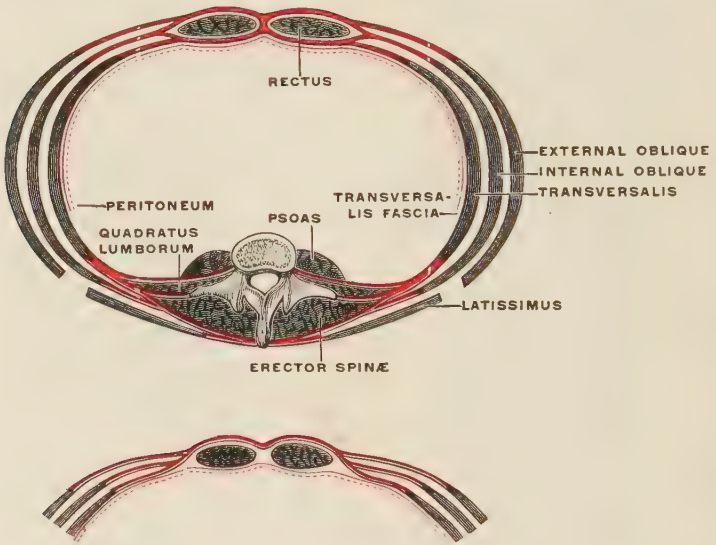


Fig. 169.—Semidiagrammatic horizontal section of trunk to show the lumbar fascia and the tendons of the lateral abdominal muscles. The upper figure shows the complete sheathing of the rectus in its superior portions; the lower shows the arrangement in its inferior fourth. (Testut.)

alba. The posterior half of the aponeurosis of the internus and that from the transversalis passes to the rear of the rectus, and forms the posterior part of its sheath, then joins the other fibers to form the linea alba.

The aponeurosis of the externus at the lower part, just above the body of the pubis, presents diverging fibers that form an opening, the external abdominal ring, the outer opening of the inguinal canal. (See text-books that go into more details.)

Obliquus Internus Abdominis. (Figs. 167 and 169.)

Location.—In the second layer on the lateral wall of the abdomen.

Origin.—Outer half of Poupart's ligament; the middle lip of the anterior two-thirds of the crest of the ilium, and the lumbar fascia.

Insertion.—Lower border of the cartilages of the six lower ribs; ensiform process; linea alba; crest of the os pubis and iliopectineal line.

Nerve Supply.—Lower intercostals, ilioinguinal and iliohypogastric.

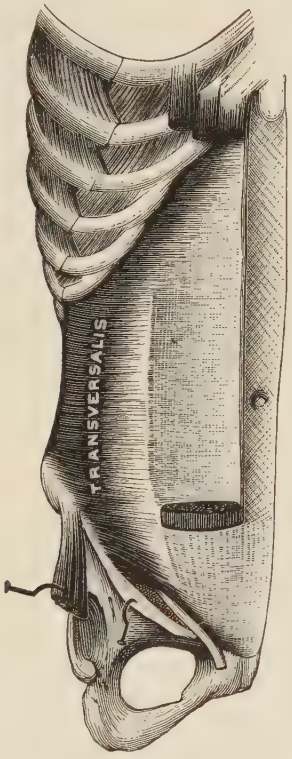


FIG. 170.—Transversalis abdominis of right side. (Testut.)

Action.—Depresses the thorax; compresses the abdominal viscera; flexes the spine; side bend and rotate to same side, when only one side acts; and when thorax is fixed, flexes and rotates the pelvis to the opposite side.

Transversalis Abdominis. (Fig. 170.)

Location.—Deep in the lateral wall of the abdomen.

Origin.—Inner side of the cartilages of the six lower ribs; inner lip of the iliac crest; lateral half of Poupart's ligament and the lumbar fascia.

Insertion.—Linea alba; iliopectineal line and crest of the pubis, by the conjoined tendon of itself and that of the internus.

Nerve Supply.—Lower intercostals, ilioinguinal and iliohypogastric.

Action.—Mainly to compress the abdominal viscera. May aid in expiration by contracting the thorax.

Quadratus Lumborum. (Fig. 143.)

Location.—Deep in the posterior wall of the abdomen.

Origin.—Inner lip of the iliac crest; transverse processes of three or four lumbar vertebræ; iliolumbar ligament and lumbodorsal fascia.

Insertion.—Last rib; transverse processes of three or four lumbar vertebræ.

Nerve Supply.—First three or four lumbar.

Action.—Lateral flexion of the spine; both acting together, extends spine; depresses and flexes the twelfth rib, in forced expiration.

THE MUSCLES OF THE THORAX.

Diaphragm	Levatores costarem
Intercostales externi	Triangularis sterni
Intercostales interni	Subcostales

Diaphragm. (Fig. 171.)

Location.—Between the thoracic and abdominal cavities.

Origin.—From the front of the bodies of the upper two lumbar vertebræ (four vertebræ on the right side), and the intervertebral disks, two *crura* are formed which arch over from one side to the other, and form an opening through which passes the aorta.

The ligamentum arcuatum internum, forms a fibrous band which passes from the body of the first lumbar vertebra to the tip of its transverse process, while the ligamentum arcuatum externum passes from the tip of the transverse process to the last rib. These arch over the psoas magnus and the quadratus lumborum, respectively. Inner surface of the cartilages of the six lower ribs, interdigitating with the transversalis, and to the ensiform process.

Insertion.—The muscle fibers converge to a central, three-leaved tendon.

Nerve Supply.—The phrenic, from the cervical plexus.

Action.—Flattens the arch, so increasing the vertical diameter of the thorax, by which means inspiration follows. It is the principal muscle of inspiration. Exerts pressure upon

the abdominal organs if the front abdominal wall is not flaccid. Muscles which act at the same time as the diaphragm in respiration are classed as inspiratory muscles.

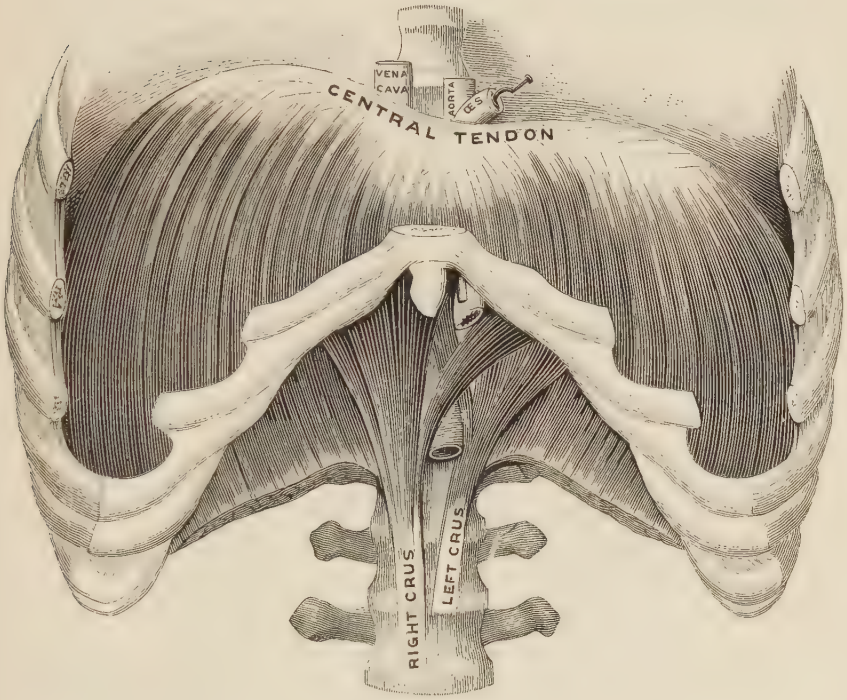


FIG. 171.—Diaphragm, viewed from in front. (Testut.)

Intercostales externi are on the outer wall of the thorax, passing between the ribs, while the **intercostales interni** are on the inner wall, filling in the spaces between the ribs. The *externi* raise the ribs, and are assisted by the *levatores costarum*, possibly, but the action of the *interni* is not agreed upon. (Fig. 125.)

The **Levatores costarum** pass between the transverse processes of the thoracic vertebræ to the dorsal surface of the rib below.

Triangularis sterni is a small triangular shaped muscle on the inner side of the thoracic wall in front. It depresses the ribs to whose cartilages it is attached.

Subcostales are small muscles, near the angle of the ribs, on the inner surface of the thorax. Their action is not well determined. The nerve supply of the above group of muscles are the respective intercostal nerves in their vicinity.

Although not on the thorax, several other muscles which have to do with respiration may be considered here. Located on the side of the neck, they act upon the upper ribs.

Scalenus Anterior.—(O. T. Scalenus anticus.) (Fig. 172.) Originating from the anterior tubercles of the transverse processes of the third to the sixth cervical vertebræ, the fibers are inserted on the upper surface of the first rib. Its action is to elevate that rib, and with the other two scaleni provide a basis for the intercostals to act in inspiratory lifting of the chest.

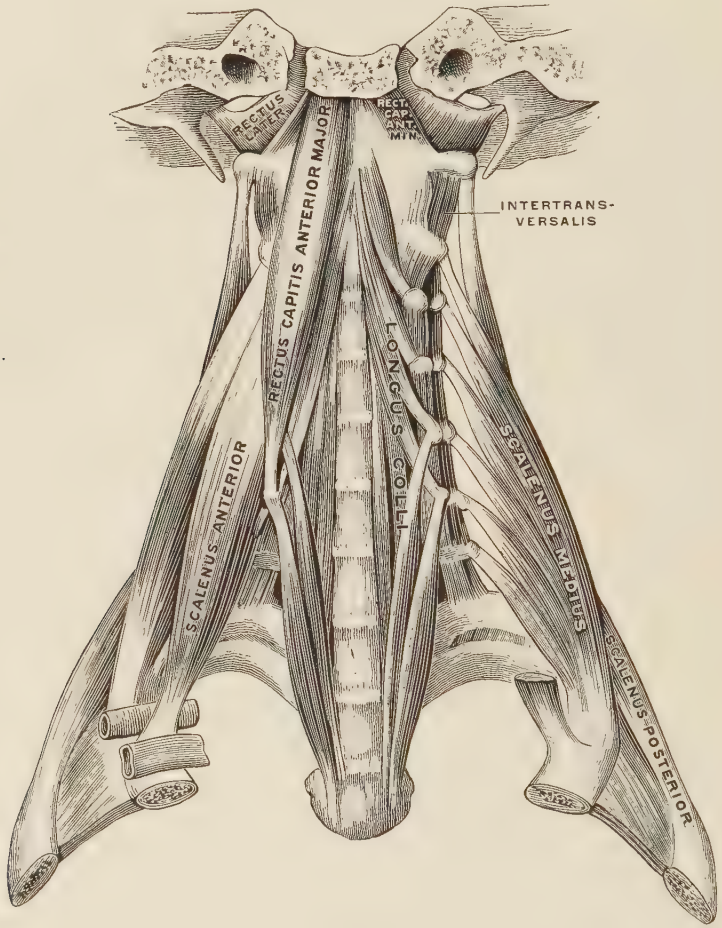


FIG. 172.—Deep lateral and prevertebral muscles of the neck. (Testut.)

Scalenus Medius. (Fig. 172.)—An origin from the transverse processes of all the cervical vertebræ, and insertion into the upper surface of the first rib, gives this muscle the same action as the preceding.

Scalenus Posterior.—(O. T. Scalenus posticus.) (Fig. 172.) Coming from the transverse processes of the lower two or three

cervical vertebræ, it is inserted into the outer surface of the second rib in front of the angle. Action, a part of the group as above.

The nerve supply of the group is from the cervical nerves in the vicinity.

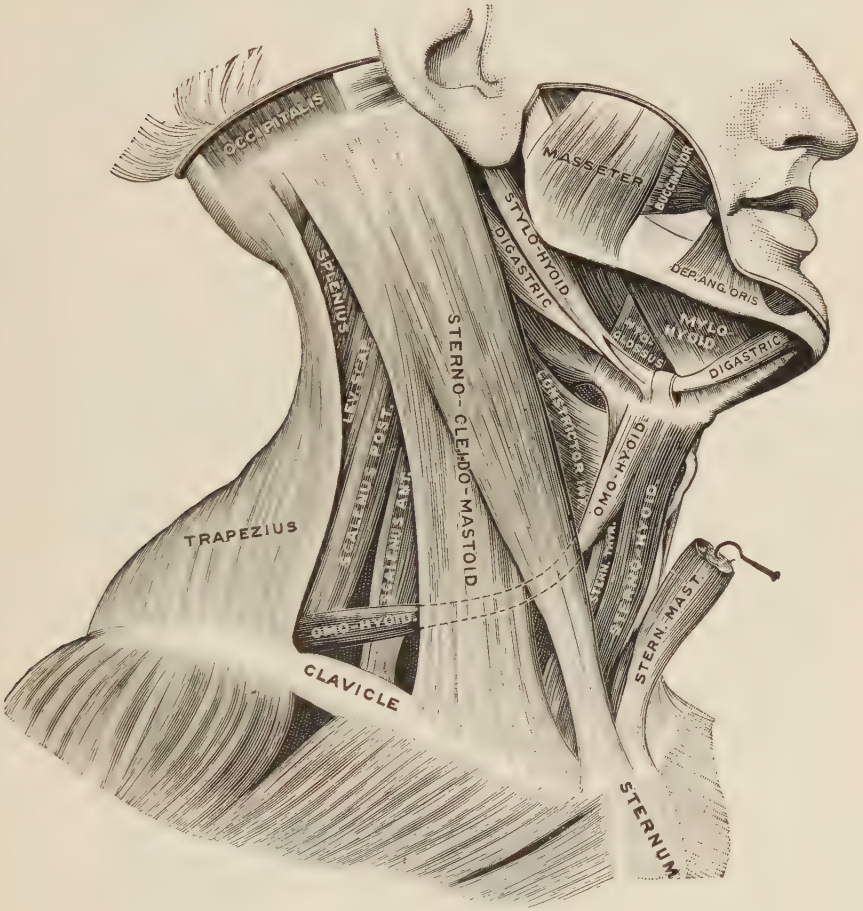


FIG. 173.—Muscles in front and side of neck. (Testut.)

THE MUSCLES OF THE HEAD AND NECK.

Sterno-cleido-mastoideus. (Fig. 173.)

Location.—Superficial on the front and side of the neck.

Origin.—The inner third of the upper border of the clavicle, and the upper border of the sternum.

Insertion.—Mastoid process of the temporal bone; outer half of the superior curved line of the occipital bone.

Nerve Supply.—Spinal accessory and second cervical.

Action.—When one side acts, it draws the head to the side, and turns the face to the opposite side. When both muscles act, they extend the head.

Platysma. (Fig. 174.)—A thin sheet of fibers passing between the clavicle and the chin, drawing down the angle of the mouth and the lower lip, and contracting the skin of the neck.

A group of muscles, some above, some below the hyoid bone, and connecting the latter with the lower jaw or the upper part of the thorax, need be mentioned only. Their function has largely to do with deglutition.

Digastricus. (Fig. 173)
Stylohyoideus. (Fig. 173)
Mylohyoideus. (Fig. 173)
Geniohyoideus.
Sternohyoideus. (Fig. 173)
Omohyoideus. (Fig. 173)
Sternothyroideus. (Fig. 173)
Thyrohyoideus.

A group of muscles, deep in the front of the neck, of which the first bends the neck sideways, and the others flex it forward, are,

Rectus capitis lateralis. (Fig. 172)
Rectus capitis anterior major. (Fig. 172)
Rectus capitis anterior minor. (Fig. 172)
Longus colli. (Fig. 172)

The last group of muscles to be considered are those of expression and of mastication. They are superficial on the head, and a study of the illustrations with their names will be sufficient.

Muscles of Expression.—All supplied by the facial nerve.

Those affecting the orifice of the mouth.

Orbicularis oris. (Fig. 174)
Levator labii superioris alæque nasi. (Fig. 174)
Levator labii superioris proprius. (Fig. 174)
Zygomaticus minor. (Fig. 174)
Zygomaticus major. (Fig. 174)
Levator anguli oris. (Fig. 174)
Risorius. (Fig. 174)
Buccinator. (Fig. 173)
Depressor anguli oris. (Fig. 174)
Depressor labii inferioris. (Fig. 174)
Levator labii inferioris. (Fig. 174)

Those of the nose.

Pyramidalis nasi. (Fig. 174)
Compressor naris. (Fig. 173)
Levator labii superioris alæque nasi. (Fig. 174)
Depressor alæ nasi.

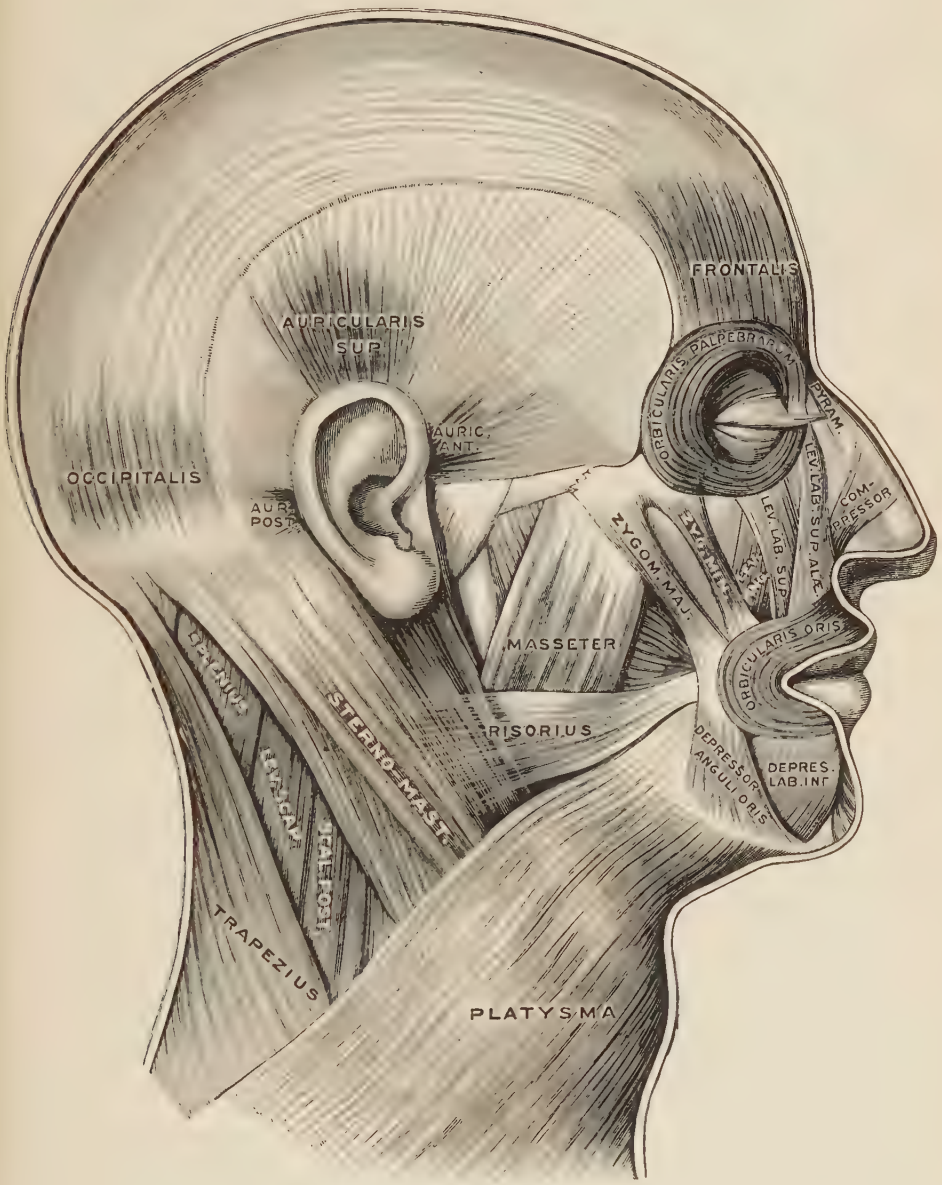


Fig. 174.—Superficial muscles of head and neck. (Testut.)

Those of the eyelids.

Orbicularis palpebrarum. (Fig. 174)
Tensor tarsi
Levator palpebræ

Those of the forehead.

Corrugator supercilii
Frontalis. (Fig. 174)

Of the occiput.

Occipitalis. (Fig. 173)

Muscles of Mastication.—Supplied by the trifacial or fifth cranial nerve.

Masseter. (Figs. 173, 174) *Pterygoideus internus*
Temporalis. *Pterygoideus externus*

GROUPING OF MUSCLES ACCORDING TO FUNCTION.

(Based Upon Morris' Human Anatomy.)

In the following table only the principal muscles are considered, omitting those given but brief mention.

Muscles Acting on the Head.

To Flex It.—The supra- and infrahyoid muscles; rectus capitis anterior major and minor.

To Extend It.—Sterno-cleido-mastoideus, trapezius, splenius capitis, trachelo-mastoideus, complexus, obliquus capitis superior, rectus capitis superior major and minor.

To Bend to Side.—Sterno-cleido-mastoideus, rectus capitis lateralis, splenius capitis, trachelo-mastoideus, complexus, obliquus capitis superior.

To Rotate It.—Sterno-cleido-mastoideus, trapezius, splenius capitis, trachelo-mastoideus, complexus, obliquus capitis superior and inferior, rectus capitis superior major and minor.

Muscles Acting on the Spinal Column.

To Flex It.—Sterno-cleido-mastoideus, longus colli, rectus capitis anterior major, psoas magnus, scaleni, rectus abdominis, obliquus externus and internus abdominis.

To Extend It.—Splenius capitis, splenius cervicis, erector spinæ, semispinalis doris and cervicis, complexus, multifidus, rotatores, interspinales, levatores costarum and quadratus lumborum.

To Bend It Laterally and Rotate.—Sterno-cleido-mastoideus, scaleni, longus colli, trapezius, levator scapulæ, splenius capitis and cervicis, semispinalis dorsi, and cervicis, complexus, multifidus, rotatores, intertransversales, levatores costarum, psoas magnus, quadratus lumborum, obliquus externus and internus abdominis, rectus abdominis.

Muscles of Respiration.

Quiet Inspiration.—External intercostals, anterior internal intercostals, diaphragm.

Forced Inspiration.—The above, and the scaleni, sterno-cleido-mastoideus, serratus posterior-superior and inferior, rhomboids, serratus magnus, latissimus dorsi, pectoralis major and minor, and the extensors of the spinal column.

Quiet Expiration.—Posterior part of internal intercostals, subcostales, triangularis sterni.

Forced Expiration.—The above and the abdominal muscles, erector spinæ, and quadratus lumborum.

Muscles Acting on the Shoulder-girdle.

Elevation.—Levator scapulæ, trapezius, sterno-cleido-mastoideus, rhomboidei, serratus magnus, omo-hyoideus.

Depression.—Trapezius (lower part) pectoralis major (lower part) pectoralis minor, subclavius, latissimus dorsi.

Abduction.—Serratus magnus, pectoralis major and minor.

Adduction.—Trapezius, rhomboidei, latissimus dorsi.

Rotation, with Abduction of Arm.—Serratus magnus (lower part), trapezius, upper part, levator scapulæ.

Rotation with Adduction of Arm.—Rhomboidei, trapezius (lower part), serratus magnus (upper part), pectoralis major (lower part), and latissimus dorsi.

Muscles Acting on the Arm at the Shoulder-joint.

Abduction.—Deltoideus, supraspinatus, biceps (long head), pectoralis major.

Adduction.—Pectoralis major, latissimus dorsi, teres major, coraco-brachialis, long head of triceps.

Flexion.—Pectoralis major, deltoideus (clavicular portion), subscapularis, coraco-brachialis, biceps (short head), and serratus magnus.

Extension.—Deltoideus (posterior part), teres major, latissimus dorsi.

Outward Rotation.—Infraspinatus, teres minor.

Inward Rotation.—Subscapularis, deltoideus (anterior part), teres major, latissimus dorsi, and pectoralis major.

Muscles Acting on the Forearm.

Flexion (Forearm Supinated.)—Brachialis, biceps (long head), brachio-radialis, biceps (short head), extensor carpi radialis longus, pronator teres, flexor carpi radialis, extensor carpi radialis brevis, palmaris longus.

Flexion (Forearm Pronated or in Mid-position.)—Brachialis, brachio-radialis, biceps, extensor carpi radialis longus and brevis, pronator teres, flexor carpi radialis and palmaris longus.

Extension.—Triceps and anconeus.

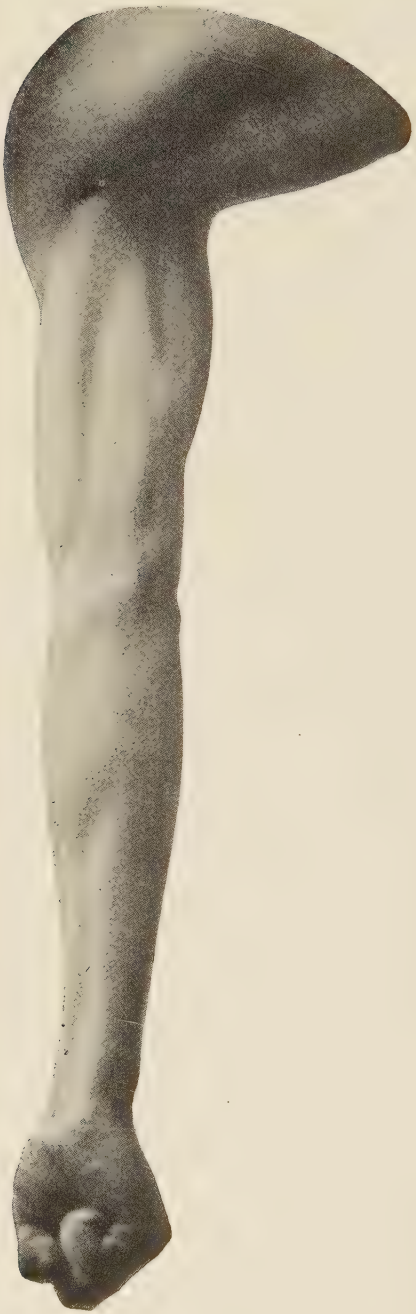


Fig. 175.—The right upper limb abducted and supinated, viewed from in front. (Gerrish.)

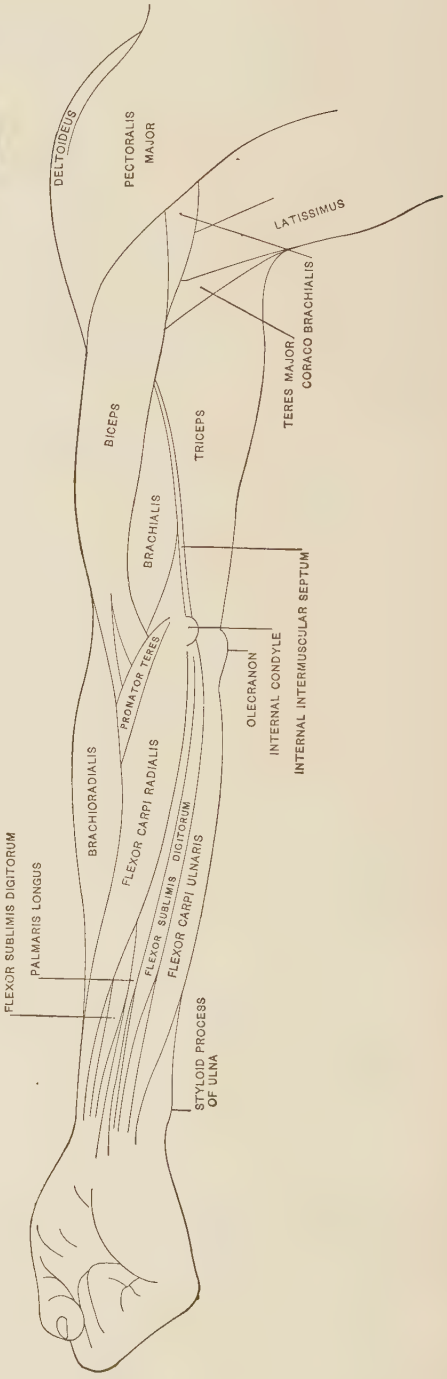


Fig. 176.—Key to Fig. 175. (Gerrish.)

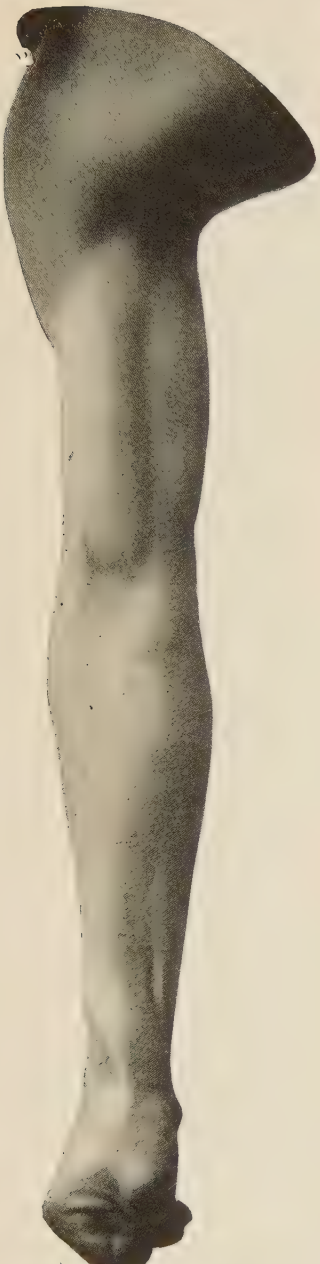


Fig. 177.—The right upper limb abducted and pronated, viewed from in front. (Gerrish.)

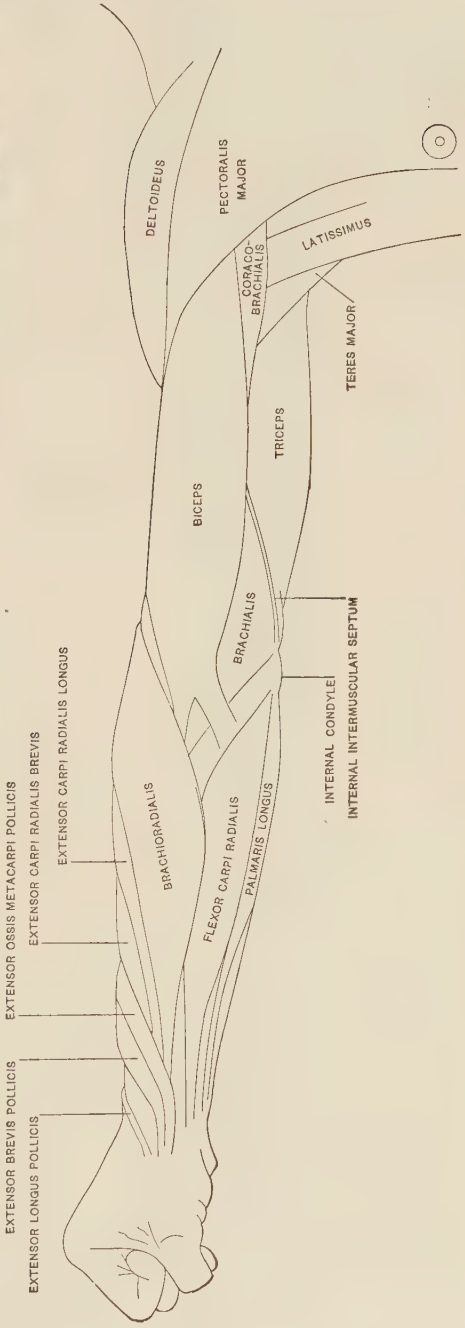


Fig. 178.—Key to Fig. 177. (Gerrish.)

Fig. 179.—The right upper limb, abducted and supinated, viewed from behind. (Gerrish.)

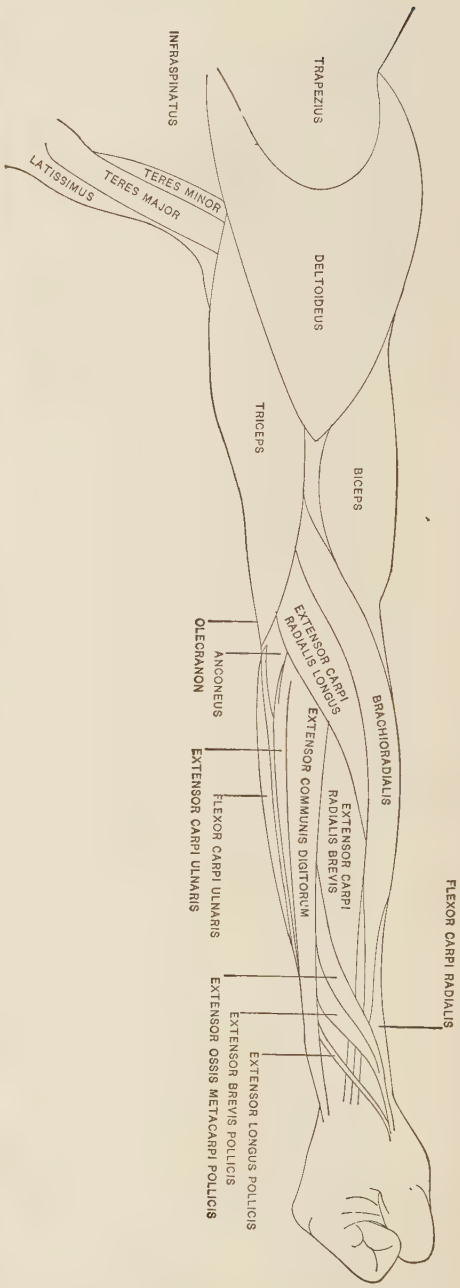


Fig. 180.—Key to Fig. 179. (Gerrish.)

Fig. 181.—The right upper limb, abducted and pronated, viewed from behind. (Gerrish.)

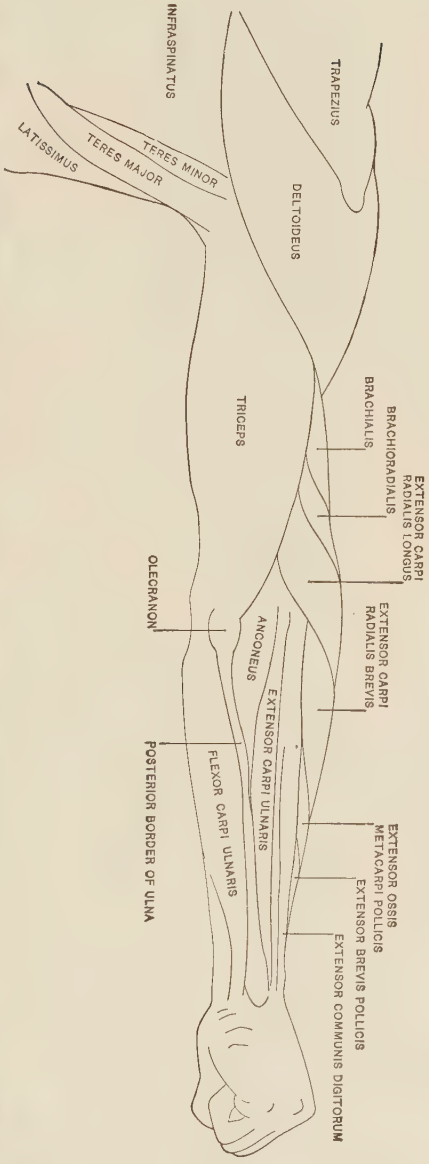


Fig. 182.—Key to Fig. 181. (Gerrish.)

Fig. 183.—The right lower limb, front view. (Gerrish.)

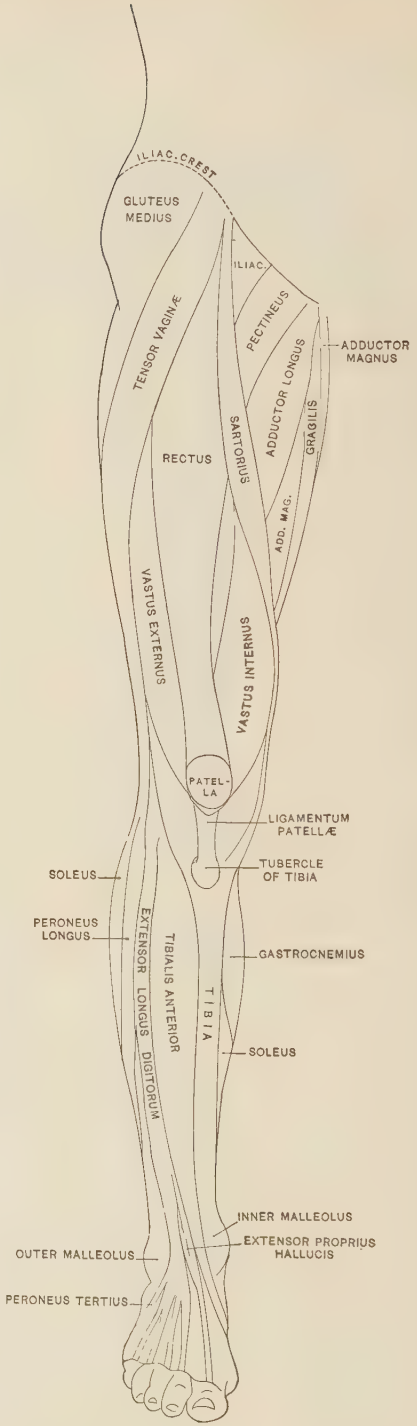


Fig. 184.—Key to Fig. 183. (Gerrish.)

Fig. 185.—The right lower limb, rear view. (Gerrish.)

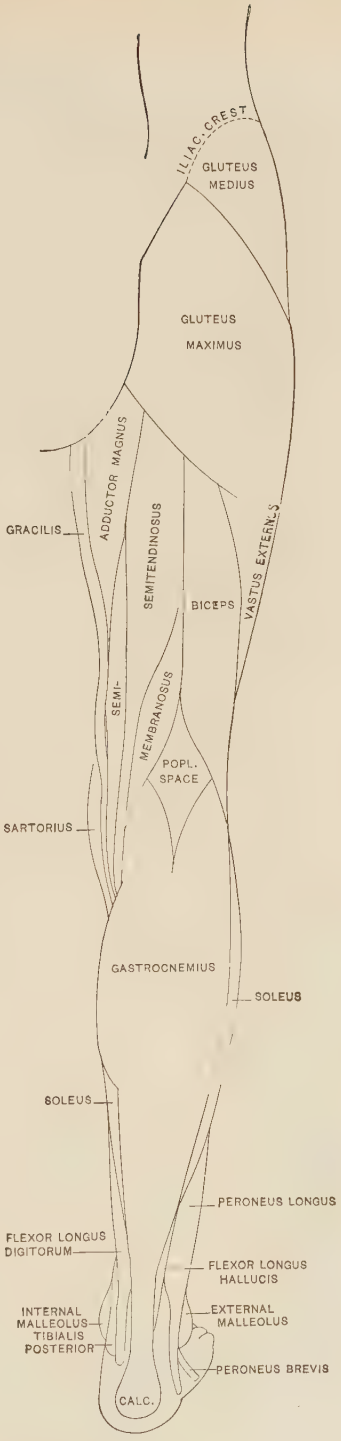


Fig. 186.—Key to Fig. 185. (Gerrish.)

Fig. 187.—The right lower limb, external lateral view. (Gerrish.)

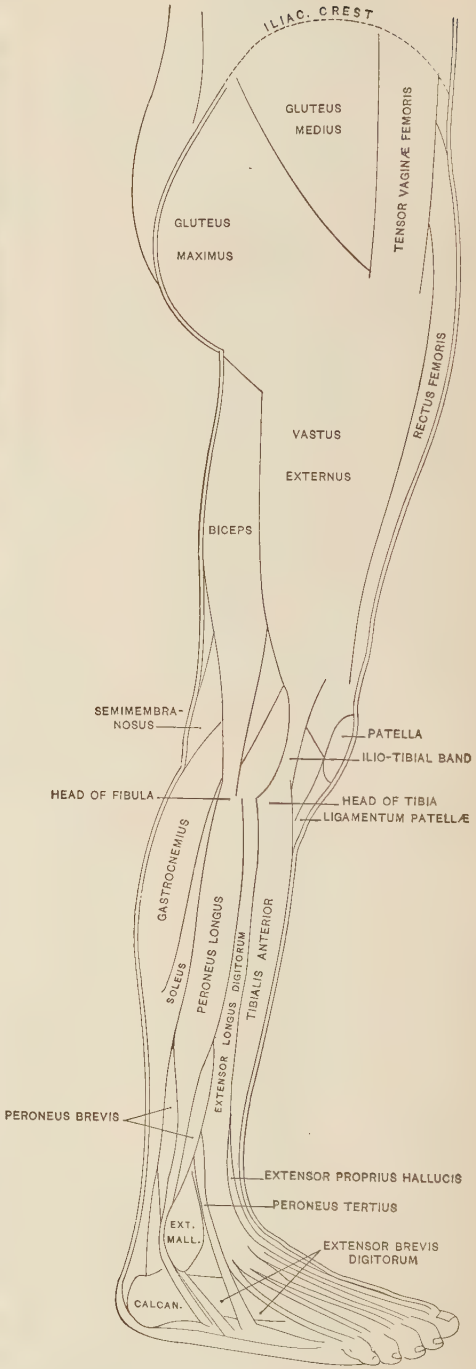


Fig. 188.—Key to Fig. 187. (Gerrish.)

Muscles Acting on the Forearm—(*Continued*)

Pronation of Forearm (Forearm Extended.)—Pronator teres, flexor carpi radialis, pronator quadratus, palmaris longus.

FIG. 189.—The right lower limb, internal lateral view. (Gerrish.)

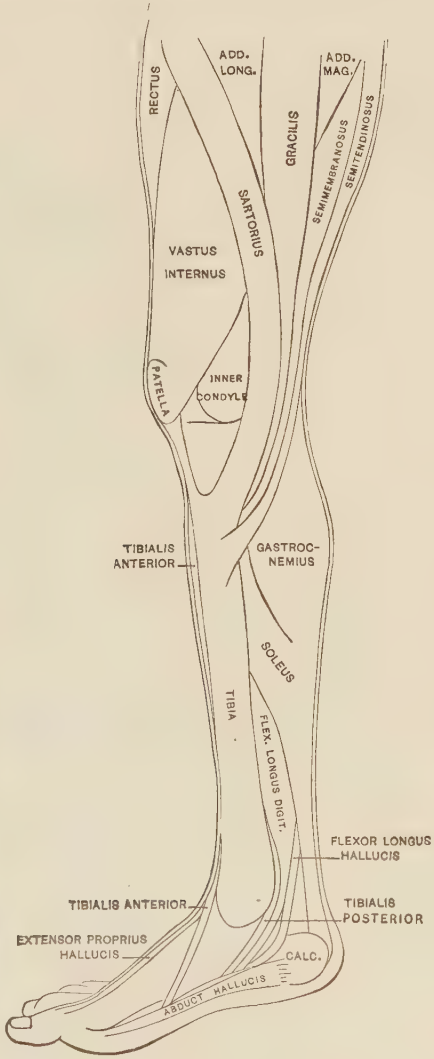


FIG. 190.—Key to Fig. 189. (Gerrish.)

Pronation of Forearm (Forearm at Right Angles.)—Pronator teres, brachio-radialis, flexor carpi radialis, pronator quadratus, extensor carpi radialis longus and palmaris longus.

Pronation of Forearm (Forearm Flexed.)—Pronator teres and quadratus, brachio-radialis, flexor carpi radialis, extensor carpi radialis longus, and palmaris longus.

Supination of Forearm (Forearm Extended).—Brachio-radialis, biceps, supinator, extensor carpi radialis longus, abductor pollicis longus, extensor pollicis brevis and longus, extensor indices.

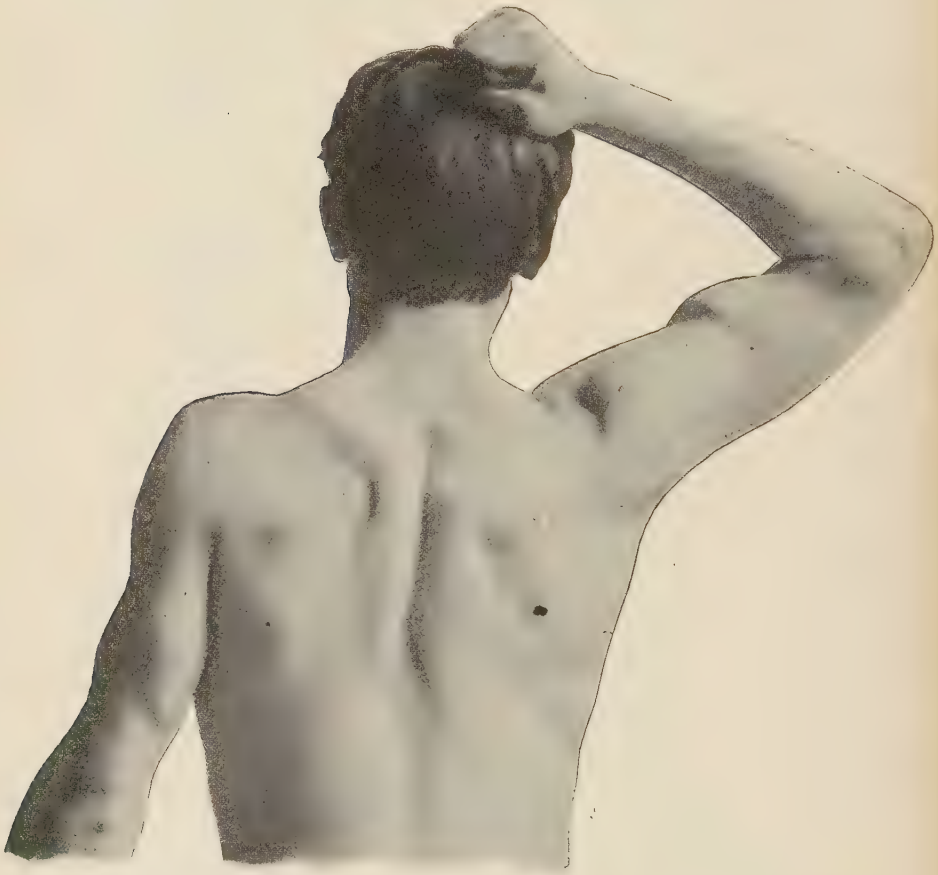


FIG. 191.—Comparison of shoulders and arms in different attitudes. The sliding outward of the scapula when the arm is raised is very marked. (Gerrish.)

Supination of Forearm (Forearm Flexed.)—Biceps, supinator, extensor longus and brevis pollicis, extensor indicis, abductor pollicis longus (extensor ossis metacarpi pollicis).

Muscles Acting on the Hand at the Wrist.

Flexion.—Flexor carpi radialis and ulnaris, palmaris longus, the long flexors of the fingers and thumb.

Extension.—Extensor carpi radialis longus and brevis, extensor carpi ulnaris, and the extensors of the fingers and thumb.

Abduction.—Extensor carpi radialis longus and brevis, extensor ossis metacarpi pollicis, extensor brevis pollicis, flexor carpi radialis.

Adduction.—Flexor carpi ulnaris, extensor carpi ulnaris.

Muscles Acting on the Fingers.

Flexes All the Joints.—Flexor profundus digitorum.

Flexes All But the Last.—Flexor sublimis digitorum.

Flexes the First Only.—Flexor minimi digiti, lumbricales and interossei.

Extends the Fingers.—Extensor communis digitorum, extensor indicis, extensor minimi digiti.

Muscles Acting on the Thumb.

Flexes All Joints.—Flexor longus pollicis. The *carpo-metacarpal* joint, extensor ossis metacarpi pollicis, flexor ossis metacarpi pollicis.

Extends All Joints.—Extensor longus pollicis.

Muscles Acting on the Pelvis.

Flexion.—Rectus abdominis, obliquus internus and externus abdominis, psoas magnus.

Extension.—Erector spinæ and multifidus.

Lateral Flexion with Rotation.—Rectus abdominis, obliquus internus and externus abdominis, quadratus lumborum, and psoas magnus acting on one side only.

Muscles Acting on the Thigh at the Hip-joint.

Flexion.—Iliopsoas, sartorius, rectus femoris, pectineus, gracilis, adductor longus and brevis, tensor fasciæ latæ.

Extension.—Gluteus maximus, biceps, semitendinosus, semimembranosus, adductor magnus.

Adduction.—Gracilis, pectineus, adductors magnus, longus and brevis, quadratus femoris, obturator externus, and lower part of gluteus maximus.

Abduction.—Gluteus medius and minimus, tensor fasciæ latæ, gluteus maximus, and when hip is flexed, pyriformis, obturator internus and gemelli.

Inward Rotation.—Tensor fasciæ latæ, gluteus medius and minimus, iliopsoas.

Outward Rotation.—Pyriformis, obturator externus and internus, gemelli, quadratus femoris, gluteus maximus and medius, sartorius, pectineus, adductor longus, brevis and magnus, biceps.

Muscles Acting on the Leg at the Knee-joint.

Flexion.—Sartorius, gracilis, semitendinosis, semimembranosus, biceps, gastrocnemius, popliteus.

Extension.—Quadriceps extensor cruris.

Inward Rotation (When Flexed.)—Sartorius, gracilis, semitendinosis, semimembranosus, popliteus.

Outward Rotation (When Flexed.)—Biceps femoris.

Muscles Acting on the Foot at the Ankle-joint.

Flexion.—Tibialis anterior, extensor longus digitorum, extensor longus hallucis, peroneus tertius.

Extension.—Soleus, gastrocnemius, flexor longus hallucis, peroneus longus and brevis, tibialis posterior, flexor longus digitorum.

Inversion at Medio-tarsal Joint.—Tibialis posterior and anterior.

Eversion at Medio-tarsal Joint.—Peroneus longus brevis and tertius.

NOTE.—The exact function of many muscles has not been determined decisively. What a muscle should do according to the law of mechanics is not always conclusive of what it really does, influenced by the action of antagonistic and fixator muscles.

Most of the muscles are placed in pairs, symmetrically on the two sides of the body, and the few that are described as single, have two sides. Some muscles are not constantly present, and in every cadaver something is likely to be lacking.

The number of muscles of the body, according to the differences in description, is given by varying authors as 400 to 622. Less then 100 pairs have been presented here as necessary for the student in physical education to really study and know.

QUESTIONS.

What muscles connect the head with the scapula?

What muscles connect the arm with the ribs?

What muscles connect the pelvis with the arm?

Name the flexors of the forearm.

Name the extensors of the thumb and fingers.

What muscles adduct the hand?

Name some muscles that pass over two joints.

What muscles extend the leg upon the thigh?

Name the adductor muscles of the thigh.

Which muscles extend one joint and flex the joint below?

Name the muscles that supinate the foot.

What is the action of the gluteus maximus?

On which surface of the tibia do the flexors of the foot find attachment?

Name the divisions of the erector spinæ, with a general description of the muscles.

What muscles form the abdominal wall?

Describe the diaphragm.

Compare the functions of the muscles of the upper extremity with those of the lower extremity.

Trace the outlines of muscles on yourself or on a fellow student by contracting same and noting boundaries. Observe any variation between those on the right and left sides.

CHAPTER VI.

GENERAL CONSIDERATION OF BURSÆ AND FASCIÆ.

The small synovial sacs which are called bursæ are very numerous, but it is unnecessary to consider more than a limited number of them, or those that are at the larger joints.

In certain locations bursæ are always found, because they are needed to enable the muscle or tendon under which they are placed to function smoothly. (See page 120.)

Where an occupation causes an excessive amount of pressure over bone, bursæ may be developed in self-defense, as with cobblers who hold a stone on the thighs and pound their leather on it. This bursa develops between the rectus femoris and the vasti muscles. Or, as they hold the shoe against their breast-bone, there is a new bursa formed.

Persons who carry heavy burdens on their shoulders develop a bursa over the spine of the scapula, where the pressure is most marked.

The bursæ considered here are those in relation to the shoulder-elbow-, knee- and ankle-joints.

BURSÆ IN RELATION WITH THE SHOULDER-JOINT.

The *bursa trapezii,* is located between the trapezius muscle and the triangular space at the root of the spine of the scapula.

The *bursa acromialis subcutanea,* is placed between the acromion process and the skin over it.

The *bursa subacromialis* is between the capsular ligament of the shoulder-joint and the arch made by the coracoid and acromial processes, and extends beneath the deltoideus muscle. This is sometimes called the *bursa subdeltoidea.* This bursa is very liable to injury and inflammation, producing marked impairment in the use of the arm.

BURSÆ IN RELATION WITH THE ELBOW-JOINT.

The *bursa bicipito-radialis,* is placed between the tuberosity of the radius and the tendon of the biceps muscle.

The *bursa olecrani subcutanea,* is between the dorsal surface of the olecranon and the overlying skin.

BURSÆ IN RELATION WITH THE KNEE-JOINT.

A large number of bursæ exist about the knee-joint, of which the following should be noted.

The *bursa sartorii* is placed between the sartorius muscle and the inner tuberosity of the tibia, separating the tendon of the sartorius from those of the gracilis and semitendinosus muscles.

The *bursa semimembranosus* is between the tendon of the semimembranosus muscle and the inner tuberosity of the tibia.

The *bursa tibialis interna* is placed between the internal lateral ligament of the knee-joint and the tendons of the inner hamstrings; sartorius, gracilis and semitendinosus muscles.

The *bursa bicipitis cruris* is between the external lateral ligament of the knee-joint and the tendon of the biceps femoris muscle.

The *bursa poplitei* is placed between the origin of the popliteus muscle on the external condyle of the femur and the external tuberosity of the tibia and the capsular ligament of the knee-joint.

The *bursa suprapatellaris* is between the quadriceps extensor cruris muscle and the lower part of the shaft of the anterior surface of the femur.

The *bursa prepatellaris subcutanea* is located between the skin and the anterior surface of the patella.

The *bursa infrapatellaris* is placed between the ligamentum patellæ and the anterior surface of the upper part of the tibia.

The *bursa condyli externi* is between the external condyle of the femur and the skin.

The *bursa condyli interni* is between the internal condyle of the femur and the skin.

The *bursa pretibialis* is between the tubercle of the tibia and the overlying fascia.

BURSÆ IN RELATION WITH THE ANKLE-JOINT.

The *bursa postcalcanea profunda*, lies between the posterior surface of the os calcis and the tendo Achillis.

The *bursa malleoli externi subcutanea* is placed between the external malleolus and the skin.

The *bursa malleoli interni subcutanea* is between the internal malleolus and the skin.

THE FASCIÆ.

Fasciæ are fibrous sheets which are wrapped around various organs, especially muscles, serving to keep them in definite and intimate relation with each other. The term also includes certain strong fibers that connect bony parts.

The fasciæ include two varieties, superficial and deep. The

typical superficial fascia is the continuous layer of areolar tissue directly under the skin, connecting and separating the skin from the deeper structures, including the deep fascia. It contains fat cells, forms a bed for bloodvessels and nerves on their way to and from various organs. There is much variation in the thickness of this superficial fascia from a very thin and delicate membrane to the big-meshed and heavy structure. Over the abdomen and the buttocks the meshes are large, frequently holding an enormous accumulation of fat cells, even several inches thick. Except on the palms and soles which are held firmly, the superficial fascia allows the skin to move with considerable freedom.

The deep fasciæ are strong, close sheets of white fibrous tissue. They appear as iridescent, pearly-white structures, very flexible and non-elastic. Sometimes they are really the spread-out tendon of a muscle. At times they serve as ligaments, and are generally in close association with other forms of fibrous tissue as tendons, periosteum, etc. While they sheathe muscles, they also pass between as *septa* and connect them.

While all the muscles are covered by fascia, in certain localities there is a thickening and accentuation of it. In the upper extremity at the wrist are transverse bands of fibers which are called *annular ligaments,* anterior and posterior respectively. They hold the tendons in place, keeping them from flying out, as they pass from the forearm into the hand. See Figs. 133, 136, pages 151, 155.

On the palm of the hand the *palmar fascia* is particularly strong and dense. It is sometimes an expansion of the tendon of the palmaris longus. It gives protection to the nerves and bloodvessels in the palm and adds much to the strength of the "grip."

The *lumbar fascia* is essentially a combination of spreàd-out tendons, though it also covers some muscles as a sheath. Fig. 169, page 194. The tendons of the latissimus dorsi, serratus posterior inferior, obliquus internus abdominis and transversalis abdominis muscles help to form this fascia, though they are frequently described as arising from it. It is attached to the spines and transverse processes of the lumbar and sacral vertebræ, to the last rib and to the outer lip of the posterior third of the crest of the ilium. It forms three layers, and invests as a sheath the quadratus lumborum and erector spinæ muscles, besides giving attachment to them.

The Fascia Lata.—The fascia lata is a very strong and dense sheath covering the entire musculature of the thigh, and sending some fibers to help make the capsular ligament of the knee-joint. It is a single layer in most of its extent, but splits so as to encase the gluteus maximus and the tensor fascia lata muscles. It is more dense on the outer aspect of the thigh.

The contraction of the tensor fasciæ latæ tightens this fascia and adds much to the efficiency of the other muscles of the thigh.

Annular Ligaments of the Ankle.—At the ankle, transverse bands of fibers form an annular ligament to hold the tendons which pass into the foot from flying out when their muscles contract. There are three divisions of the ligament, anterior, internal and external.

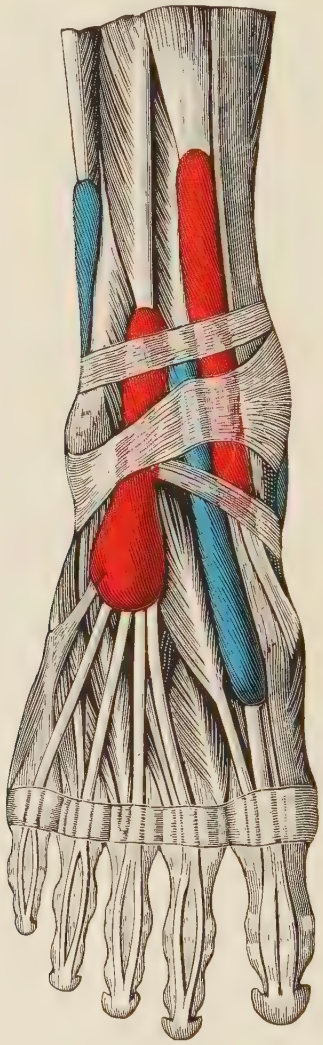


Fig. 192.—The anterior annular ligament of the ankle and the synovial membranes of the tendons beneath it artificially distended. (Testut.)

The anterior annular ligament holds down the tendons of the extensor longus digitorum, peroneus tertius, tibialis anterior, and extensor proprius hallucis muscles (Fig. 192).

The internal annular ligament holds down the tendons of tibialis posterior, flexor longus digitorum and flexor longus hallucis muscles (Fig. 193).

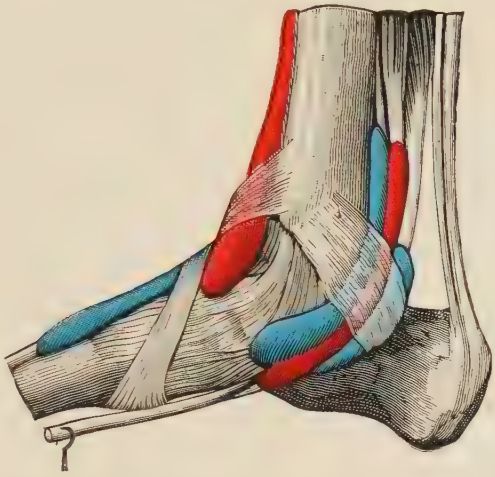


FIG. 193.—The internal annular ligament of the ankle and the artificially distended synovial membranes of the tendons which it confines. (Testut.)

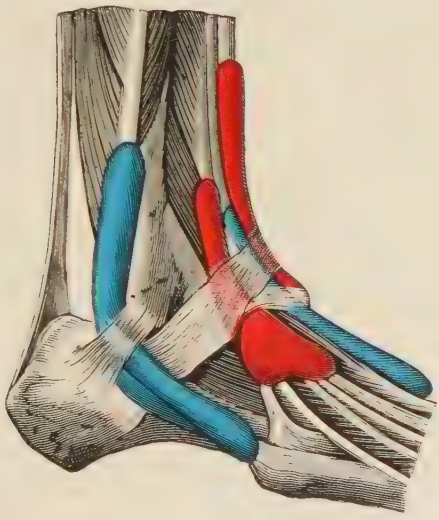


FIG. 194.—The external annular ligament of the ankle and the artificially distended synovial membrane of the tendons which it confines. (Testut.)

The external annular ligament holds down the tendons of the peroneus longus and peroneus brevis muscles (Fig. 194).

Plantar Fascia.—On the sole of the foot where the bloodvessels and nerves are peculiarly susceptible to injury in walking, the layer of fascia is very dense and thick. Transverse bands hold in place the tendons which move the toes.

Connection of Fasciæ and Veins.—In most of the joints of the body, but especially at the shoulder, lower part of the neck, the elbow-, knee- and hip-joints, the deep fascia is attached to the fibrous covering of the large veins in those regions.

When the joint is moved, the fascia is pulled and in turn it pulls upon the veins, opening out the latter and creating a partial vacuum. This is instantly filled by the rush of blood and thus serves as a suction pump in returning the venous blood to the heart, as it cannot go in the opposite direction on account of the valves.

When the pull is released, the veins return to their former caliber, and this presses upon the blood, sending it along toward the heart. Thus the deep fasciæ serves an important use in the circulation of the blood.

QUESTIONS.

What is a bursa?
Where are bursæ placed?
What results from an inflammation of the bursa subacromialis?
What joint needs and has the greatest number of bursæ?
What is the "fascia lata?"
What is the "annular" ligament of the wrist?
What would probably result if there was no "annular" ligament of the ankle?

CHAPTER VII.

THE NERVOUS SYSTEM.

The nervous system is divided into two parts, the *cerebrospinal* and the *sympathetic* or *autonomic*.

The cerebrospinal system is the seat of conscious knowledge, of will, of coördination, of thought and of sensation. With this part of the nervous system we see, hear, taste, smell, feel, think. After assembling these sensations we make such responses by motion as the will ordains. Or, we even respond by motion without the will being concerned. All the so-called higher faculties are lodged in the cerebrospinal axis.

Anatomically the cerebrospinal system consists of the cerebrospinal axis, the cranial and spinal nerves.

The cerebrospinal axis consists of the brain or encephalon, and the spinal cord.

GENERAL CONSIDERATIONS OF THE BRAIN, INCLUDING SOME SPECIAL CENTERS.

The Encephalon.—The encephalon is contained in the cranial cavity, and weighs on an average about three pounds. It consists of four parts, the *cerebrum*, the *cerebellum*, the *pons varolii*, and the *medulla oblongata*. The spinal cord hangs within the spinal canal.

The brain is covered by three membranes, the *pia mater*, the *dura mater* and the *arachnoid*. These are called the *meninges*.

The *pia* is next to the brain substance, and is a very delicate network of small bloodvessels, supported by areolar tissue, carrying nutrition to the various parts of the surface. It dips down into the various fissures.

The *dura* is a dense strong fibrous structure in two layers, which not only covers the brain, but serves as the periosteum of the cranial bones. These layers are closely united except in certain places. Small channels in the cranium are lined by the dura, and shelf-like processes project toward each other so that canals are formed which contain veins. These are call *sinuses*. (Fig. 195.) Prolongations of the dura serve to separate parts of the brain. The *tentorium* is that between the cerebellum and the occipital portion of the cerebrum; the *falx cerebri* is between the two hemispheres and the *falx cerebelli* separates the cerebellar hemispheres.

On the inner surface of the dura is a delicate layer of epithelial cells, with a similar layer on the outer surface of the pia. These form the arachnoid membrane, essentially a serous membrane and secreting a fluid, the *cerebrospinal fluid.*

This fluid forms a water-bed between the brain and the bones of the cranium, lessening jar. The brain is never completely at rest, and it is literally churned up and down by the varying amounts of blood going to it. The respiratory movements, and the pulsations

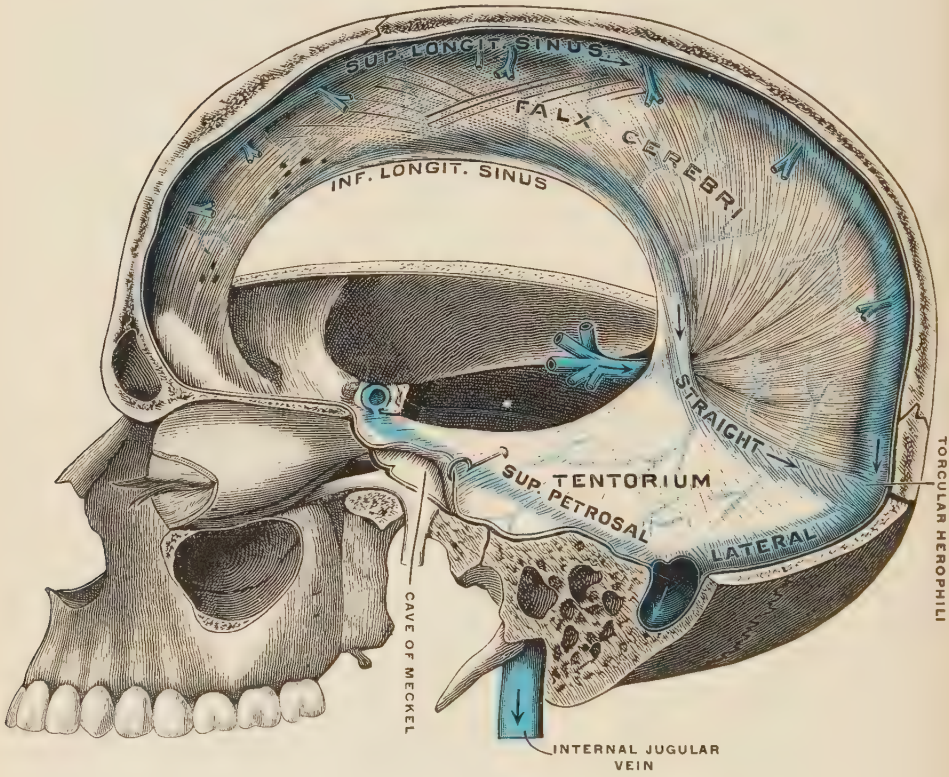


Fig. 195.—Sinuses of the dura, left lateral view. (Testut.)

of the large arteries of the brain vary in force and frequency, sometimes being very rapid and strong. The jarring effects of these are minimized by the water-bed. This fluid is also found in the spinal canal, protecting the cord.

Much of the fluid is found in hollow spaces in the center of the brain, which are called *ventricles.* Five such spaces exist and communicate with each other and with the spinal canal.

The varying amount of blood in the brain may be observed by watching the fontanelles on the head of an infant. Every time the

child inspires, the skin covering the fontanelles sinks in, while during expiration there is a bulging out.

The four divisions of the brain vary much in size. Largest of all is the *cerebrum*, or fore-brain, extending from the forehead to the occiput and filling the vault of the cranium above the eyes and ears. It is divided into right and left hemispheres.

The cerebrum rests upon the floor of the cranium, leaving but a small compartment for the rest of the brain.

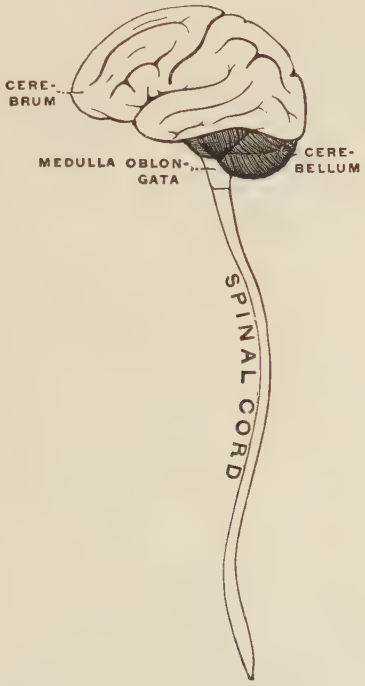


FIG. 196.—Semidiagrammatic view of the cerebrospinal axis, left side. (Testut.)

The tentorium forms a tent over the cerebellum and keeps the pressure of the posterior lobes of the cerebrum from it. The second division in size is the *cerebellum*, or hind-brain. It occupies the back part of the base of the skull. (Fig. 196.)

The *pons varolii* surmounts the medulla and is the means by which the medulla is connected with the cerebrum and cerebellum. It is the cross-roads of the brain, resting on the base of the cranium just in front of the medulla.

The *medulla oblongata* is virtually the upper end of the spinal cord expanded into a club-shaped process, and projected into the cranial cavity, resting on the base of the skull for about

$1\frac{1}{4}$ inches. Its upper portion forms the floor of the ventricular space.

The Cortex.—The tissue of the brain is divided into gray and white matter, the gray matter representing the cellular or working element, and the white matter the communicating fibers.

The gray matter is on the outside of the brain, forming a layer about $\frac{1}{4}$ inch thick, called the *cortex*.

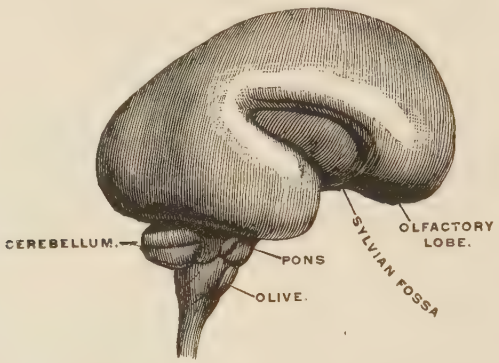


FIG. 197.—Brain of six-months' human embryo, natural size, right side. (Kölliker.)

This is an aggregation of neurons, with the axones leading out of the brain to some part of the periphery but with the branching processes in intimate association with their neighbors. As animals ascend in the scale of intelligence and brain power there is a change in the appearance of this layer of gray matter. This is illustrated by the human fetus, which at six months shows a perfectly smooth

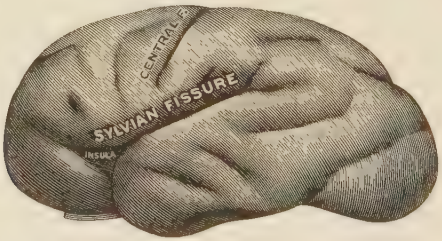


FIG. 198.—Cerebrum of eight-months' human embryo, left side. The insula is nearly covered in. (Testut.)

layer of gray matter in the cortex (Fig. 197), but shortly begins to show wrinkling and folds all over it. The wrinkles become deeper and more numerous as the brain develops and are called *fissures*. (Fig. 198.) Individuals are more able, not according to the size of their brains, but according to the depth and number of the wrinklings and in the multitude of their association neurons.

This arrangement gives space for a vastly greater number of neurons than could be accommodated on a smooth surface.

The fissures vary on the two sides of the brain and in different individuals, but correspond very constantly. (Fig. 199.)

The space between the fissures is called gyrus or convolution, and every one is named.

The *longitudinal* fissure divides the cerebrum into lateral halves. The *Sylvian* fissure starts near the center of the base of the brain, going upward and backward, then dividing into anterior and posterior limbs.

Above the Sylvian fissure in the middle region of the lateral surface is the *fissure of Rolando*, or the central fissure. It starts from the longitudinal fissure and passes downward almost to the Sylvian fissure.

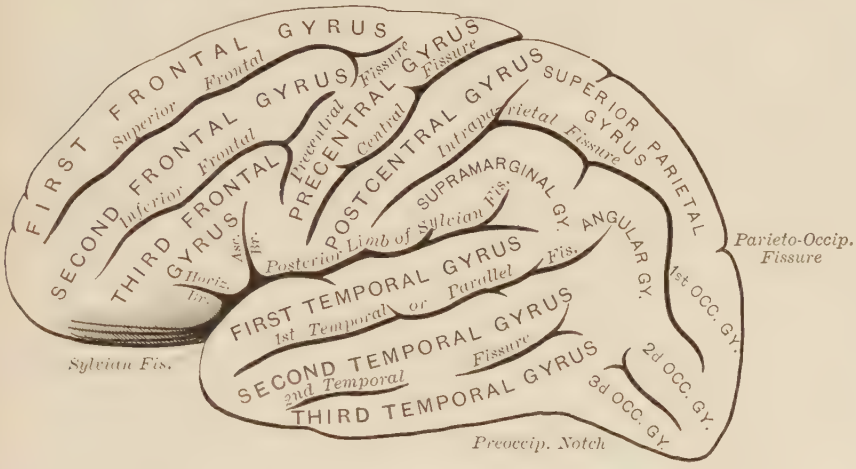


FIG. 199.—The gyri and fissures of the external lobes of the left hemisphere. (Gerrish.)

The *parieto-occipital* fissure begins far back on the upper margin of the hemisphere and continues downward and forward. These fissures mark, more or less accurately, the boundaries of four lobes of the brain, the frontal, parietal, temporal and occipital. (Fig. 200.)

A fifth lobe, the *insula* is scarcely visible from the surface, because the other lobes develop so much faster they cover it from sight. A sixth lobe is the *limbic* or *falciform*. (Fig. 201.)

These lobes form the major divisions of the cerebrum, the gyri form the divisions of the lobes, while larger or smaller fissures respectively separate them.

The Corpus Callosum.—Beneath the gray matter in the cerebrum is a large mass of white matter, the *corpus callosum.* It consists of

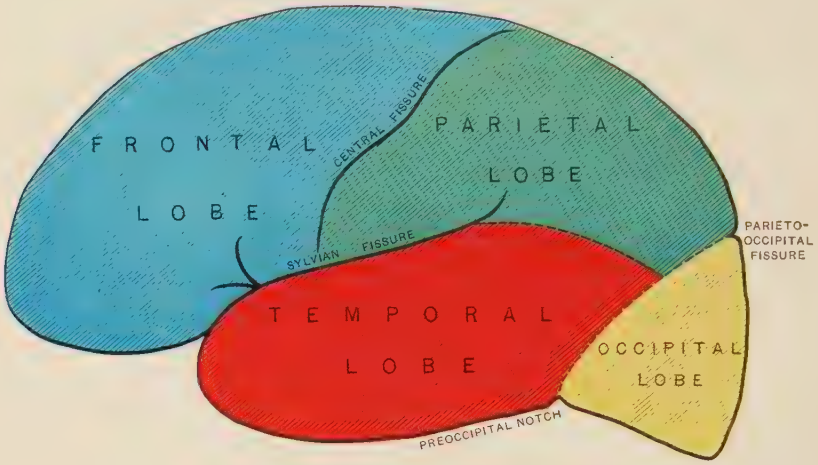


FIG. 200.—The lobes of the convex surface of the hemisphere, left side. (Gerrish.)

medullated fibers which cross from one side of the brain to the other, from one part of a hemisphere to another part. (Fig. 202.)

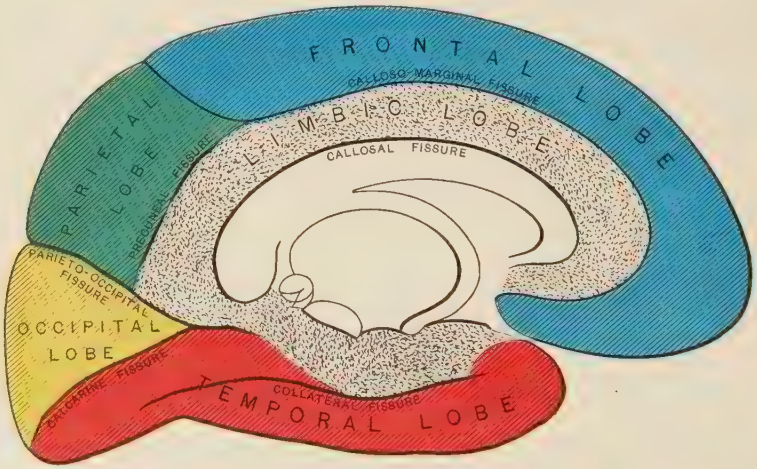


FIG. 201.—The lobes of the mesial and tentorial surfaces of the left hemisphere. (Gerrish.)

It is like a great flat band of nerve fibers which runs from side to side forming the roof of the ventricular space. By means of these,

the gray matter of one part of the cerebrum is held in close and constant communication with the gray matter of every other part. The fibers run in every direction, the arrangement being very intricate. Impressions received from the outer world are coördinated with thought, emotion and motor activity.

Every voluntary movement of the body is a complex act. It is preceded or accompanied by certain sensations or perceptions which occur in some part of the brain, dependent upon stimulation of the sensory nerves in some way, or upon experience derived from former

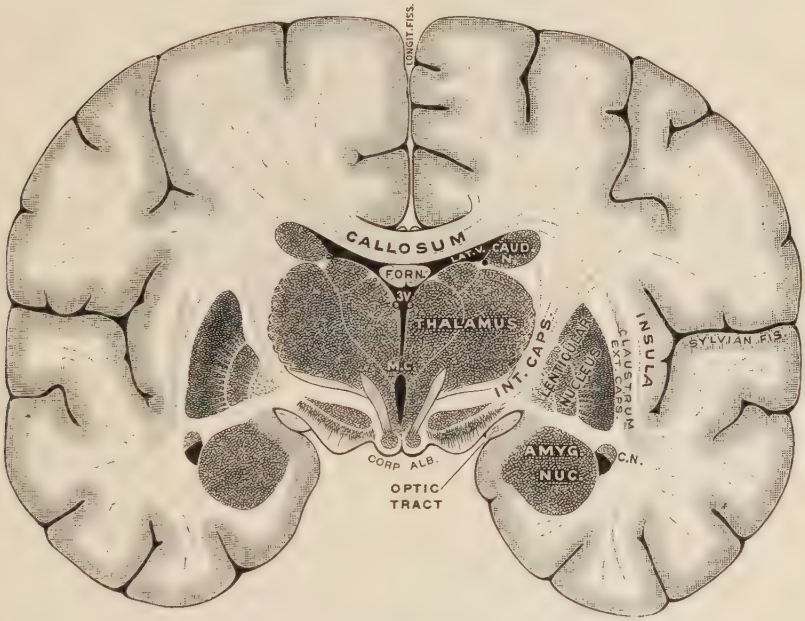


FIG. 202.—Coronal section of the hemispheres through the middle commissure: AMYG. NUC., amygdaloid nucleus; C.N., caudate nucleus in the roof of the middle horn of the right lateral ventricle; CORP. ALB., corpora albicantia; EXT. CAPS., external capsule; FORN., fornix; INT. CAPS., internal capsule; LAT. V., body of lateral ventricle; 3 V., third ventricle. (Testut.)

similar occurrences. Some mental associations are developed, with activity over large areas of the cortex before the conscious orders go out from definite areas to the muscles. These orders being for certain contractions to occur that shall produce certain movements.

In the corpus callosum are various small masses of gray matter, some of which are called "nuclei," "ganglia," "commissures," etc. On the floor of the ventricles, and the upper part of the medulla other small gray masses are found. Many of the cranial nerves originate in this area.

The Cerebellum.—The cerebellum, or hind-brain is in the posterior fossa of the cranium covered by the tentorium. Its gray matter is on the outside, projecting inward in tooth-like or dentate processes. Its main portion consists of three parts, a middle and two lateral divisions called hemispheres. The median portion, also called the vermix is very small, so it can be hardly seen. (Fig. 203.) The upper surface of the cerebellum is nearly flat (Fig. 204.) and the lower surface convex (Fig. 205).

Fissures on both surfaces run transversely, dividing the substance into layers, leaves or laminæ.

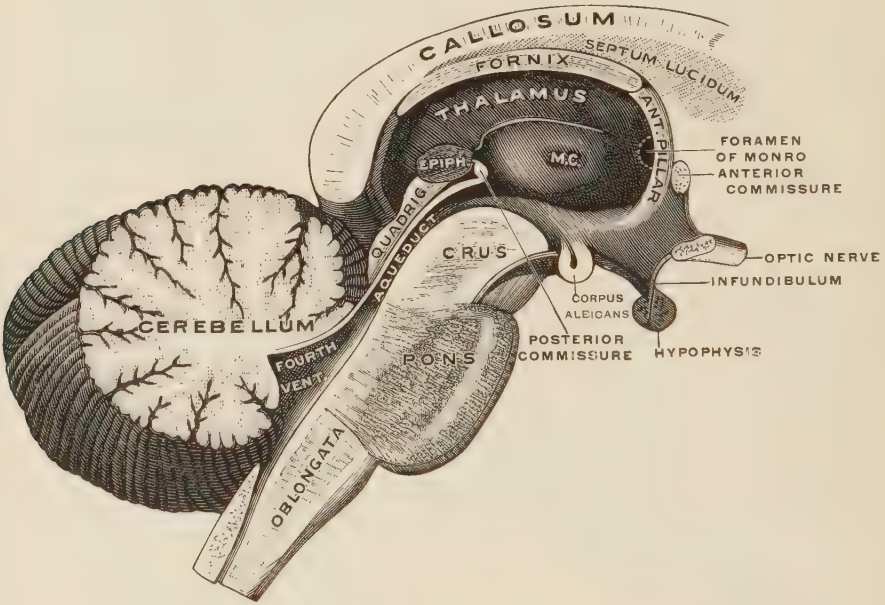


FIG. 203.—Median section through the third and fourth ventricles. Left half. M.C., middle commissure. (Testut.)

They are similar to the gyri of the cerebrum in having white fibers in a mass below, covered with gray matter. The cerebellum is connected with the other parts of the brain by three pairs of bands. One pair goes to the medulla, one to the pons and the other pair to the mid-brain or isthmus. (The isthmus is a narrow neck by which the cerebellum is connected with the structures below.)

The Pons Varolii or Bridge of Varolius.—This structure is mainly composed of fibers which run in various directions. One set goes through the central part connecting the isthmus to the medulla. Another set passes horizontally, connecting the two lateral hemispheres of the cerebellum.

In the midst of these white fibers are several collections of cells, among which are the nuclei or places of origin of the fifth, sixth, seventh and eighth cranial nerves.

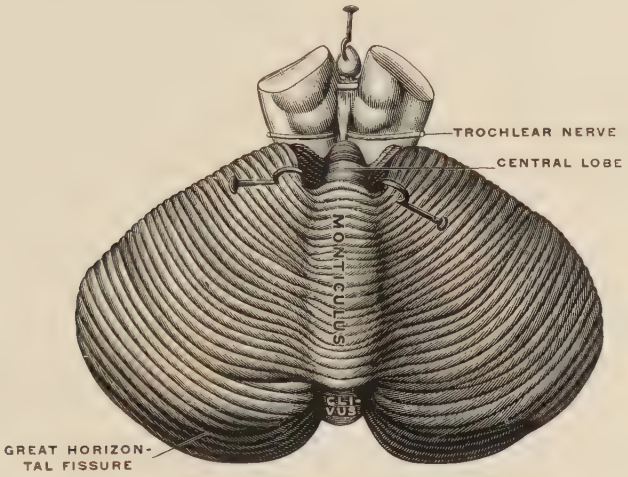


FIG. 204.—Upper surface of cerebellum. The lingula and cacumen are concealed by overhanging parts. The label "monticulus" is on the culmen. (Testut.)

The Medulla Oblongata.—This is also known as the medulla or spinal bulb, and may be considered as a connecting link between

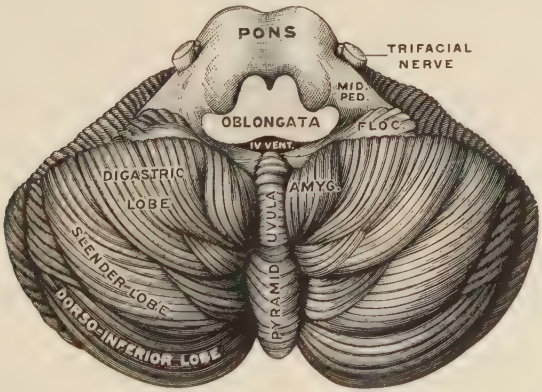


FIG. 205.—Under surface of cerebellum. The hemispheres are pulled apart to give a view of the inferior vermis. The nodule is between the uvula and the fourth ventricle. (Testut.)

the spinal cord and other parts of the brain. In its structure it presents similarities to both.

As the other parts of the brain have been considered, it will be well to turn ahead to the section describing the spinal cord so as to note the relations of the medulla to both.

In comparing the medulla with the cord it should be noted that while in the brain the gray matter is mostly on the outside, in the cord it is in the center, shaped crudely like a letter "H." The white substance is separated by the legs of the "H" into three columns on each side, ventral, dorsal and lateral. These divisions, both the gray and the white are continued upward from the cord into the medulla, but their relations are changed.

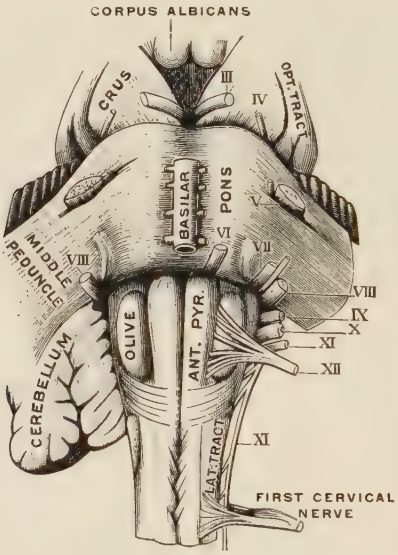


FIG. 206.—The pons and medulla, ventral view. (Testut.)

The gray matter is broken up into a number of separate parts, and there are a number of additional nuclei.

The white fibers, some of which carry messages to the brain, some from it, seem to be continued upward into the corresponding part of the medulla, but this is not always the case, and the bundles of fibers may be turned in new directions in a very complicated fashion.

The medulla rests upon the basilar process of the occipital bone, is about $1\frac{1}{4}$ inches long, extending from the lower margin of the pons to the beginning of the spinal cord just below the "decussation of the pyramids." It is larger above, tapering below to about the same size as the upper region of the cord. (Fig. 206.)

The Decussation of the Pyramids.—On the ventral surface of the medulla is a longitudinal fissure, the *ventro-median fissure,* which

is interrupted by a criss-cross of nerve bundles. On each side of the fissure is a white body which seems to be directly continuous with the ventral column of the cord. These are the *ventral* (anterior) *pyramids*, and their crossing over the fissure at their lower part, so

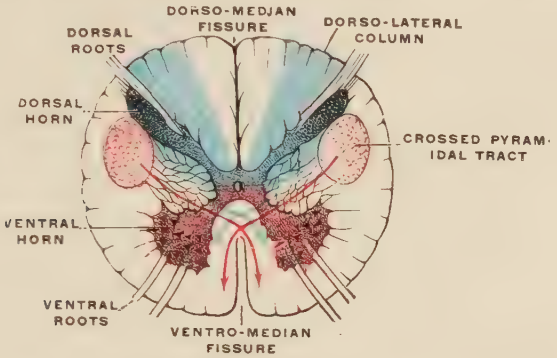


FIG. 207.—Transverse section of the medulla at its lower end. (Testut.)

the fibers on the right go to the left side, is called the "decussation of the pyramids." This is the arrangement by which the left side of the brain controls the right side of the body, and *vice versa*. (Figs. 207, 208.)

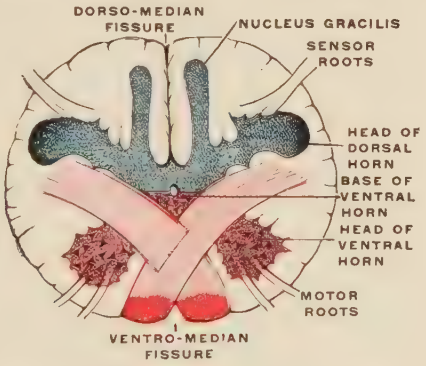


FIG. 208.—Transverse section of medulla at the decussation of the pyramids. (Testut, after Duval.)

From the medulla, come the cranial nerves from the sixth to the twelfth, inclusive, and the first spinal nerve.

Functions of the Cerebrum.—For many centuries it has been recognized that the cerebrum is the seat of conscious sensation and intelligence. It has been known that the development of the brain was connected with and dependent upon the development of the cortical area of the cerebrum.

If, for any reason the sutures of the skull in an infant are united before the brain has had time to develop, the mentality of the child, to a greater or less degree, will be stunted.

Injuries to certain areas of the cortex have resulted in loss of memory. These facts and certain experiments show that if the cortex is removed all the sensation, intelligence and thought that characterize the highest psychical life of man is destroyed. Abnormalities of the cortical structure may be the cause of the perverted reasoning of the insane and the characteristics of the degenerate.

The cortex of the cerebrum contains a variety of nerve cells, arranged in some five layers. Some of these cells are supposed to have only the work of connecting one part of the cortex with another part. Some are shaped like a pyramid and are called "pyramidal" cells. Many of these send their axones to the medulla.

The pyramidal cells of the motor areas of the cortex give rise to the out-going messages which proceed along their axones to the motor nuclei of the cranial or spinal nerves. From the cells of these nuclei, other axones carry the messages to the muscles or other parts that are to be stimulated. There may be intermediate stations where the impulse is accentuated or augmented, as the axones pass through the cerebellum or medulla, but there must always be these two stations. Some axones from the brain, cross from one side to the other at the "decussation of the pyramids," going down to the spinal neuron on the opposite side to that in which the impulse originated.

Areas of the Brain—Motor and Sensory.—The cortex is a vast aggregation of neurons. Some of the cells receive messages by afferent or sensory axones, some cells send out messages by efferent or motor axones. Some neurons are *intermediaries*.

Apparently, every sense organ, the eye, the ear, the nose, the tongue and the skin, has its own place where messages are received. Muscle and visceral sensations likewise have their areas, all somewhat posterior to the Rolandic fissure.

The motor areas from which voluntary muscles are stimulated are mostly grouped about the Rolandic fissure, more in front of it, and comprise those for the head and eyes, the face, the arm, the leg and the trunk muscles. These areas follow the order in which the cranial and spinal nerves emerge from the brain and cord.

The higher psychic centers are assigned to the frontal lobe. The visual center is in the back part of the parietal and the occipital lobes. The auditory centers are in the temporal lobe, back of the Sylvian fissure.

The center for speech, located in Broca's convolution in the posterior part of the frontal lobe, has been thought to exist on the left side only. Persons with right-sided paralysis, due to lesions on the left side of the brain, are generally unable to speak, but if the

paralysis is on the left side, showing involvement of the right side of the brain, the power of speech is generally present. As nearly all the brain functions are bilateral, it is thought there may be an undeveloped speech center on the right side of the brain that may be made to function by the development, by motor education of the right side areas.

These various sensory and motor centers, however extensive, are of no use without the mediation of *association neurons*, which pass between the sensory and psychic neurons, and the psychic and motor neurons. (Fig. 209.) It is thought that more than one-half of the cortex is occupied by the association neurons. Through the interrelations thus established, and the working of the higher psychic centers, volitional impulses are evolved, and the most com-

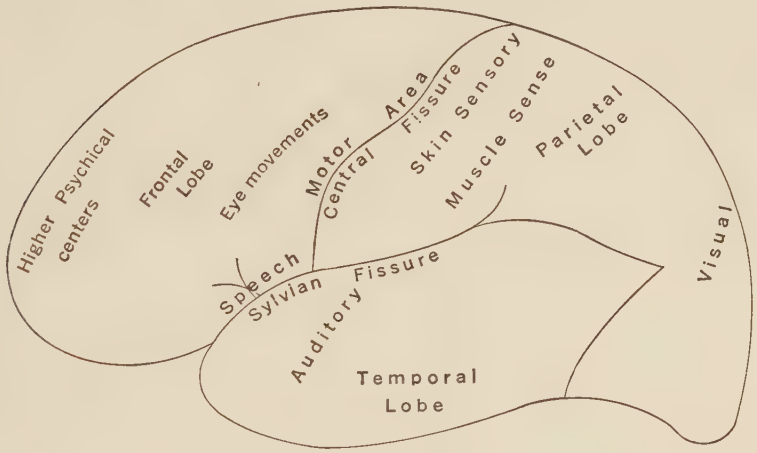


FIG. 209.—Some of the areas in the cerebrum.

plicated processes occur. Writing, for instance involves memory of signs representing ideas, their arrangement so they will be understood by others, and the painfully acquired motor activity of hand and arm.

These are all functions of the cortex of the cerebrum, largely developed through motor activity. *No* motor activity means *no* cortical development.

Reflexes.—Messages are carried to the brain by "afferent" nerves, while the "efferent" nerves carry a message from the brain to the periphery. Both are concerned in most actions, as the messages coming from the outside to the brain provoke some response, that is, some reflex, either of the voluntary or involuntary sphere.

As an instance, a bright light thrown into the eye causes the reflex of contraction of the pupil. A touch on the eyeball, causes

the reflex of winking. The smell of appetizing food starts the secretion of saliva. Such reflexes are impossible to control or prevent, and are spoken of as *unconditional reflexes.*

Another kind of reflex, called *conditioned reflexes* may be obtained under certain conditions or may be brought out by training or education. They are subject to various forms of inhibition both internal and external. The method of obtaining them is as follows. If a certain sensory stimulation is given, as a note of a definite number of vibrations per second, there is no effect upon the secretion of saliva, but, if the salivary glands are stimulated by acid at the same time, after a while the reflex of salivary flow comes from the note alone without the acid.

Many reflexes occur through the mediation of the cerebral cortex, and many others through the spinal cord. Those of the spinal cord however, may be inhibited by the brain. The involuntary jump that occurs upon hearing a sudden loud noise may be inhibited by the higher centers in the brain, so that in time, the individual makes few involuntary movements, or noticeable reflex actions.

The simplest reflex requires a certain number of elements. There must be an irritation at some peripheral point; an afferent or sensory nerve to convey this impression to the sensory cells in either the brain or spinal cord; a process to carry this impression to the dendrites of an efferent or motor neuron, and an axone from the motor cell to a skeletal muscle. This arrangement provides for a very simple reflex, and elicits a single muscular contraction.

Strong peripheral irritations have the same mechanism plus some intermediate elements. The impression from the sensory cell may go by its dendrites to the dendrites of an association neuron in the brain, or of a correlation neuron in the spinal cord to the efferent or motor neurons in many segments of the cord, initiating a reflex muscular action out of all proportion to the original irritation.

A person, tickled in the ribs, may go into a spasm of muscular contraction that is very extensive, but not necessarily coördinated. A "conditioned" reflex may be obtained from sensitive subjects by merely pointing the finger at their ribs.

Or, the irritation may go so far up the cord it reaches the medulla, with a resulting reflex both extensive and coördinated. These responses are made through the skeletal muscles which ordinarily respond to volitional stimuli, alone.

The various functions of the body, as the movements of respiration, the inhibition or excitation of the heart action, the variation in the caliber of the bloodvessels, the excitation or inhibition of the contraction of the muscles of the digestive tract, and the stimulation to secretion of the epithelial cells of glands, are all instances of reflex action.

In respiration, the presence of a certain amount of CO_2 in the

blood irritates certain cells in the medulla, from which impulses go to the motor cells in the "inspiratory center." Thence are emitted the messages to the various muscles concerned in the inspiratory movements of the thorax and the harmonizing of their action.

The activity of the sweat glands is a fairly complex reflex. An external temperature of over 70° F. will serve as an irritant to the

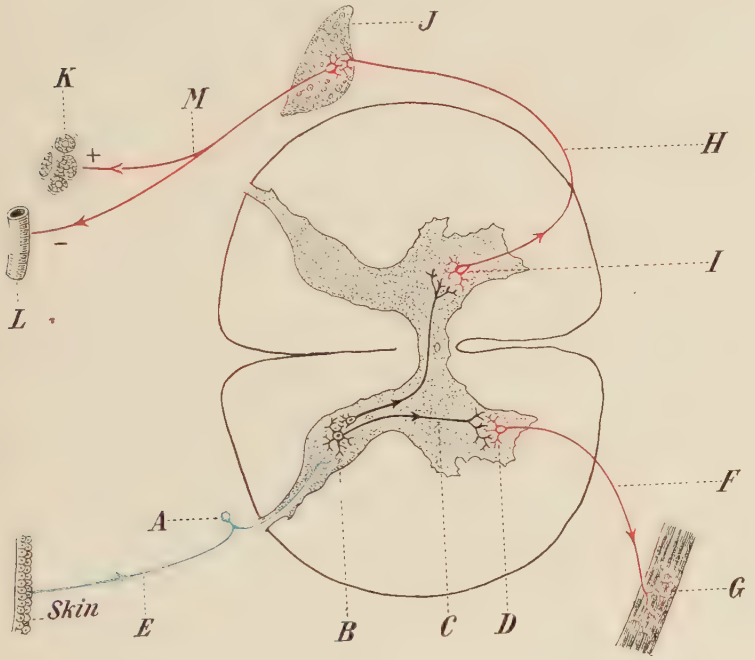


FIG. 210.—Diagram to illustrate reflex action. *A*, ganglion on sensory nerve root; *B*, cell of correlation neuron; *C*, axone of same; *D*, motor cell; *E*, sensory nerve from skin; *F*, motor nerve to muscle; *G*, muscle; *H*, preganglionic fiber, from cell I in lateral horn; *J*, sympathetic ganglion, with neuron outlined; *M*, postganglionic fiber from cell in *J*; *K*, sweat gland stimulated to activity (+); *L*, arteriole, whose circular fibers are inhibited (−).

Sensation from the skin may eventuate in a movement of the voluntary muscles, with a correlation neuron carrying on a message. Or a sensation from the skin may eventuate in the formation of sweat, and increased blood supply to skin, with a correlation neuron as intermediary.

The lower part of the diagram illustrates a reflex action in the cerebrospinal sphere. The upper portion shows the pathways in the autonomic sphere.

sensory nerves of the skin. The message of this irritation is carried by the fibers to the cells in the posterior horns of the gray matter of the cord. Then, by correlation neurons to the vasomotor and sweat centers in the medulla. Efferent impulses pass down to the cells in the lateral horns of the gray matter, at various levels, outward in the motor roots of the spinal nerves of a greater or lesser number of

segments of the cord to the cells of nearby ganglia of the sympathetic. Axones from these ganglionic cells go to the walls of the cutaneous bloodvessels, inhibiting their contraction, so they dilate, and to the epithelial cells of the sweat glands, stimulating them to secrete. (Fig. 210.)

Functions of the Cerebellum.—It is supposed that the cerebellum coördinates muscular movements—especially those concerned in equilibrium and locomotion. This coördination appears to be largely reflex. The principal elements involved are sensory impulses from the skin, muscles, eyes and the *semicircular canals* of the ear, together with motor impulses of various neurons in the cerebellum and the general muscles of the body. It may be an augmenting apparatus for voluntary movements. There is a lack of agreement among physiologists in regard to the work done by the cerebellum. Its loss seems to affect the muscular sense and those of position and direction. Each half is connected with the corresponding half of body.

Functions of the Medulla.—A number of "centers" are located in the medulla and pons, which through an intricate coördinating mechanism of cells and fibers control a number of so-called "automatic" functions.

1. A vasomotor center for the whole body, controlling the amount of blood going to areas according to the need of the part.
2. A cardiac center regulating the rate of the heart, through both accelerator and inhibitory fibers.
3. A respiratory center, controlling the muscles of inspiration.
4. A diabetic center, having to do with the conversion of glycogen to sugar.
5. An articulation center, which controls the coördination of the muscles involved in speech.
6. Centers for insalivation, mastication and swallowing.

THE BLOOD SUPPLY OF THE BRAIN.

The brain is supplied with blood from the arteries that form the "circle of Willis" or arise from it. (Fig. 253.) This extensive anastomosis provides an abundant supply at all times even if the internal carotid or the vertebral artery is shut off.

The veins which drain the brain are called *sinuses*. These are foldings of the *dura mater*, which, with grooves in the cranial bones form large, firm canals, which are capable of withstanding considerable pressure. (Fig. 195.) Several of these sinuses unite at the *torcular Herophili*, from whence the blood is carried through the lateral sinuses to the *internal jugular vein*, to the *brachiocephalic vein* and to the *superior vena cava*.

The Circulation in the Brain.—This is different from that in other organs in that the brain is enclosed in a rigid bony case that limits expansion. As the blood is sent out from the heart, the aorta and other large vessels expand. In the thorax the surroundings are soft enough to allow such increase in size. In the cranium the rigid walls limit it, so great damage would be done to the brain unless provision was made for the swelling. During systole the wave of blood coming into the cerebral arteries increases the size of the brain. This is met by a displacement of the *arachnoid fluid* into spaces outside the cranial cavity. A part of the increase is cared for in this way. The pressure of the brain upon the veins of the *pia mater* lessens their caliber, and so the rate of flow through them increases.

This carries the blood off more rapidly—enough to compensate for the arterial expansion. It also develops a *pulse* in the jugular vein, as the arterial pulse is transmitted through virtually rigid tubes.

The familiar feeling of "fulness" in the head, when taking exercises sufficiently strenuous to increase the heart rate, and, at the same time, holding the breath in expiration, is explained by this arrangement of the cranial circulation. The venous return flow to the heart depends largely upon the inspiratory movements. When these are checked the flow into the vena cava is blocked, and also the flow further back.

As no vasomotor nerves have been found in the cerebral arteries, the amount of blood going to the brain must be regulated in some other than the usual way to other organs. It is supposed that the general vasomotor control acts indirectly. If the circular fibers in the arteries are inhibited the vessels dilate. In the skin and viscera this would increase their blood supply, while lessening that to the brain. If digestion is going on very little mental work can be done, and *vice versa*. If the blood is kept out of the skin and viscera more is available for the demands of the brain.

Cerebral Work.—During waking hours there is always more or less activity of the brain. Impressions from the outside world are continually arriving, eventuating in thought or action through the mediation of the associated neurons, the intellectual or motor centers. This implies a normal irritability of the various neurons, whose activity causes metabolic changes—the development of waste materials and the need of repairs.

As work goes on the irritability lessens and the brain becomes fatigued. Other parts of the body may rest by the cessation of activity, but, as stated above, the brain is always more or less active, and so gets no rest until sleep intervenes.

Sleep.—During sleep there is much less blood sent to the brain. The heart beats less frequently and with less force. The respiratory

rate is diminished. More blood is sent to the skin and viscera. Less irritability of the organs of sense, the eyes and the ears, is present, as also with the sense of touch.

For the first two or three hours sleep is more profound, so that ordinary noises and lights make no impression upon the consciousness.

Presently, the brain having been refreshed by the removal of waste products and the coming of new materials awakens, and the normal irritability of the neurons returns.

Apparently, the fundamental condition for sleep is anemia of the brain, by the transfer of blood to the periphery. Hence, the familiar observation that warming the feet will help to induce sleep. Also, if there is insufficient covering, the excess of blood in the skin is driven back to the interior, and hence to the brain, by the chilling of the surface. This condition effectually prevents sleep.

GENERAL CONSIDERATION OF THE SPINAL CORD WITH MOTOR AND SENSORY PATHS.

The *spinal cord* or *myelon* is the second part of the cerebrospinal axis and is the direct continuation of the medulla.

It extends from the foramen magnum, or from the "decussation of the pyramids" to the lower border of the first lumbar vertebra. It is about 18 inches long, on the average, and varies in diameter from $\frac{5}{8}$ to 1 inch. It terminates in a slender filament, called the "filum terminale" (Fig. 211). The cord does not occupy the full length of the spinal canal, but from the lumbar enlargement the sacral and coccygeal nerves come off and hang down into the lower part of the canal in a formation to which is given the name, "cauda equina" or horse's tail from its resemblance to that object.

The cord has coverings similar to those of the brain, with corresponding uses. The *dura* is on the outside, extending to the intervertebral foramina; the *pia*, a delicate mesh of bloodvessels close to the cord, and the *arachnoid* between the two, producing the arachnoid fluid. This fluid serves as a water-bed or cushion to protect the cord from external violence.

From the cord on each side are given off *spinal nerves* to supply the skeletal muscles of the body below the head, and transmit the sensory impressions from the same regions.

A cross-section of the cord (Fig. 212), shows it to be composed of gray and white substance. The gray is placed in the center, the white, outside. On the surface are a number of creases. In the middle line of the front is a deep and rather broad fissure, called the *ventral* or *ventro-median fissure*. In the middle line posteriorly is a less well marked cleft, the *dorsal* or *dorso-median fissure*. At each side of the dorsal fissure, about one-fourth of the distance toward

the front is the slight *dorso-lateral fissure*, and between this and the dorsal is the *dorso-intermediate fissure*. The nerves given off from the cord arise by two roots, the dorsal root which comes from the posterior horn of the gray matter, at the dorso-lateral fissure, and the ventral, coming from the ventral horn some distance to the outer side of the ventral fissure.

The White Matter of the Cord.—Between the ventral fissure and the ventral roots the white fibers form the anterior or ventral column. Between the ventral and dorsal roots is the lateral column, while between the dorsal roots and the dorsal fissure is the dorsal or posterior column, which is subdivided by the dorso-intermediate fissure into the dorso-lateral and the dorso-median columns. (Fig. 213.)

The Gray Matter of the Cord.—The gray matter of the cord is arranged in the shape of a very crude letter "H," having the front horn or cornu much wider than that at the rear. From the posterior part of the ventral cornu the lateral cornu juts out, more pronounced in the upper dorsal region. The crossbar or *gray commissure* has an aperture which indicates a small canal, continuous throughout the cord, which is called the "central canal of the cord." It communicates with the fourth ventricle of the brain.

By reference to Fig. 215 it will be seen that the size of the cord and the proportion of gray matter varies at different levels. The cervical enlargement and the lumbar enlargement mark the giving off of spinal nerves to the upper and lower extremities respectively.

This gray matter consists of neuroglia, enclosing and supporting a network of cells, fibers, medullated and non-medullated, bloodvessels and lymphatics.

Ventral Horns.—The ventral horns of the gray matter of the cord contain large

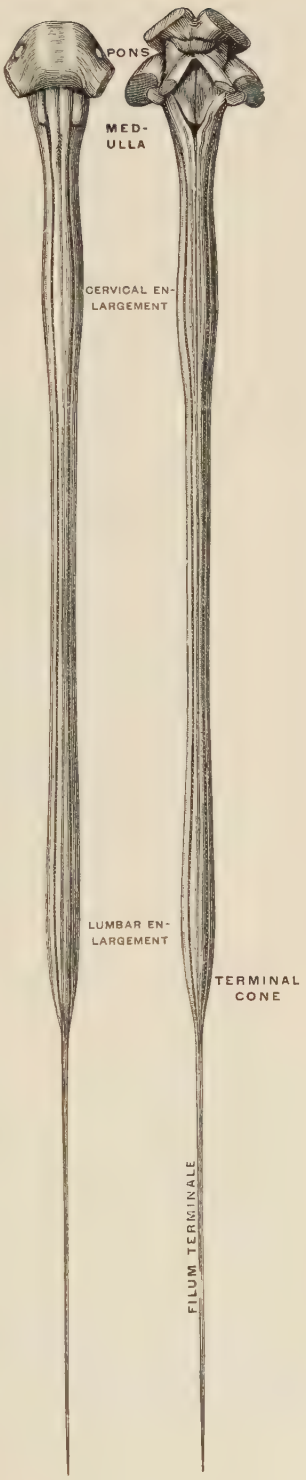


FIG. 211.—Spinal cord, medulla and pons. Left-hand figure is ventral view, right-hand is dorsal. (Testut.)

cells from which emerge large axones that go out as the ventral (anterior) or motor roots of spinal nerves, to energize the skeletal muscles.

Smaller cells are in the lateral horns in the thoracic region. These send out small axones which pass out at the ventral roots with the above, but go by way of a sympathetic ganglion and additional axones from the cells of the ganglion to the muscles in the walls of bloodvessels and hollow viscera, and to the epithelial cells of glands.

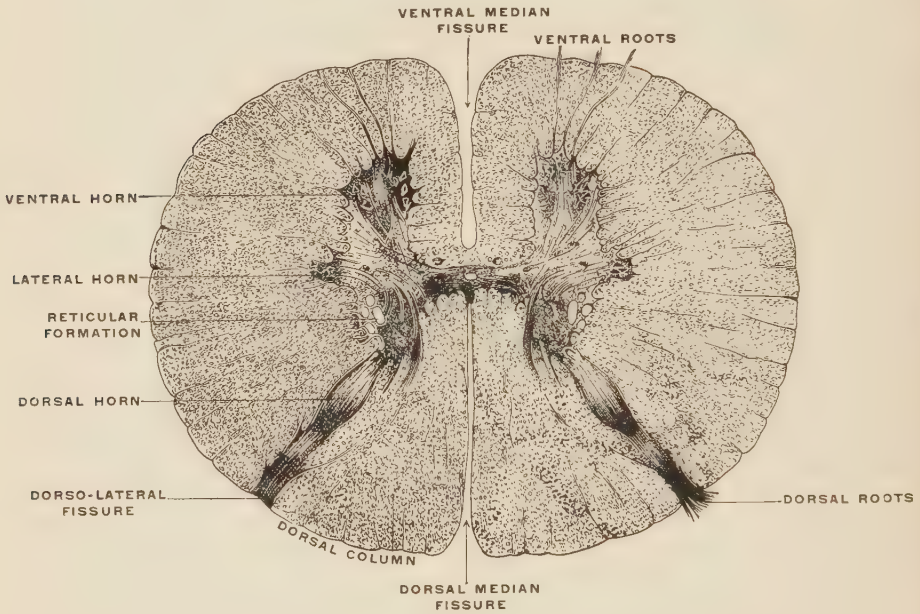


FIG. 212.—Transverse section of the spinal cord at the middle of the thoracic region. The neuroglia septum has been removed from between the dorsal columns. (Testut, after Pierret.)

Dorsal Horns.—From the seventh cervical to the third lumbar the dorsal horns contain a group of cells known as "Clarke's column." Nerve fibers entering the spinal cord through the posterior roots, and carrying sensations from muscles, joints, skin and tendons, arborize around these cells. From the cells pass axones which go out into the white columns and ascend to centers in the cerebellum, arborizing around the cells therein. From these cerebellar cells axones pass downward, which control the contraction of muscles concerned in maintaining the equilibrium of the body. (Fig. 213.)

A second group of cells receives sensations of pain, temperature, touch and pressure from cutaneous areas, and sensations from the viscera. Their axones pass to the other side of the spinal cord and

go upward in the tract of fibers internal to Gower's tract and in front of the ventral horn, ending in the postcentral convolution of the cortex. (Fig. 213.)

A third group of cells receive sensory impressions from the muscles, joints and tendons. Their axones pass upward in the

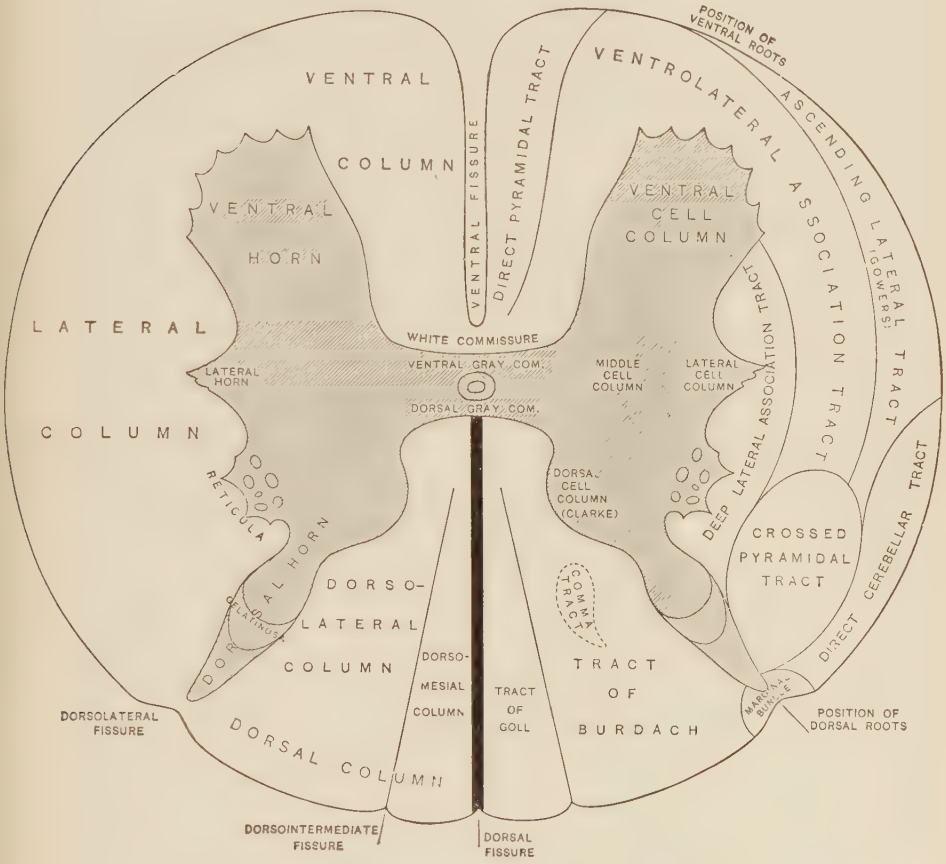


FIG. 213.—Diagrammatic ideal transverse section of the spinal cord. On the left side are shown the gross divisions; on the right side, the conduction paths. (Gerrish.)

columns of Goll and Burdach, through the medulla to areas in the cortex where they produce sensation as to the position of the various parts of the body, the direction of movements, the amount of resistance, etc. This is the "kinesthetic sense." (Fig. 213.)

Another group of cells in the dorsal horns is the so-called "correlation" neurons. Their axones branch, some going to communi-

cate with the dendrites of cells (form synapses) in the ventral horns on the same level. Other branches pass upward or downward to cells on higher or lower levels. They are concerned in transferring or amplifying stimuli which arrive at or depart from the cells in the cord. (Fig. 214.)

The *gray commissure* of the cord is formed by unmedullated fibers passing from one side of the cord to the other side.

Cells in the cord are thus, either: afferent, receiving messages; efferent, sending messages; or those whose axones serve as connecting links between the other two kinds.

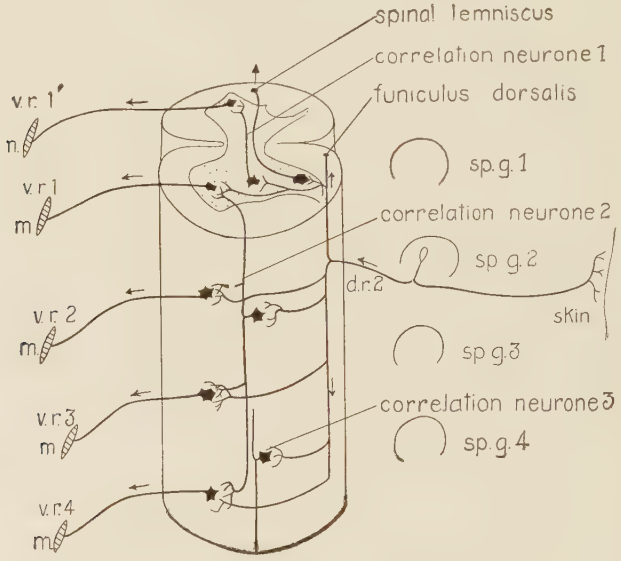


FIG. 214.—Diagram of the spinal cord reflex apparatus. Some of the connections of a single afferent neuron from the skin (*d.r.*2) are indicated: *d.r.*2, dorsal root from second spinal ganglion; *m*, muscles; *sp.g.*1 to *sp.g.*4, spinal ganglia; *v.r.*1[1] to *v.r.*4, ventral roots. (After Herrick.)

White Fibers of the Cord.—The white substance of the cord is formed by medullated fibers either going down the cord from the brain or upward to the brain. They form distinct tracts that have been pretty thoroughly traced and their functions determined. A white commissure, placed in front of the anterior part of the gray commissure, connects the two sides of the white matter in the cord.

The cord is also divided into segments corresponding to the number of the vertebræ. Each of these segments, through the spinal nerves, has a definite relation with a definite region of the body. (Fig. 217.)

Functions of the Spinal Cord.—*Conduction.*—As will be inferred from the above, the conduction of messages is the function of many of the fibers in the cord. The columns of white matter seen in the

cord do not show much difference anatomically but physiologically there is a great difference. By referring to Fig. 213 the limits of the columns may be noted.

The *direct or anterior pyramidal* tract and the *crossed pyramidal* tract convey motor impulses. The cross pyramidal tracts come directly from the pyramidal cells in the cortex, and passing through the medulla, cross from one side to the other at the "decussation of the pyramids." Fibers of the direct pyramidal tract cross from one side to the other *below* the crossing of the "crossed" tract, so that all motor impulses come out on the opposite side to that in which they originate. The right side of the body is controlled by the left side of the brain. Motor impulses from the motor areas of the brain pass down these tracts to the motor cells in the anterior cornu of gray matter in the cord, thence going by spinal nerves to their peripheral terminations.

Sensory impulses from the periphery pass into the cord, then may go through several columns to the brain. The fibers in these tracts seem to cross from one side to the other in any part, so that section of half the cord produces anesthesia of the opposite side of the body below the cut.

Association and Augmentation.—This function of the cord is performed through the correlation neurons. Fibers go from one side of the cord to the other side. They go up and down, carrying impulses to numerous areas, thereby multiplying or augmenting the reflex response. Different segments of the cord are thus brought into association.

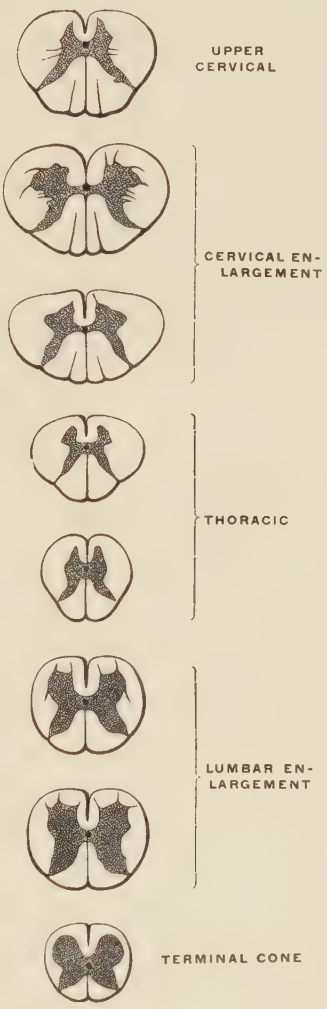


FIG. 215.—Transverse sections of the spinal cord at different levels. (Testut, after Erb.)

Transference.—Another function of the cord is the transferring of impressions from one place to another, as, in the case of pain in the knee-joint when the trouble is really located in the hip-joint.

Reflex Action.—This is one of the very important functions of the cord, and takes place without the mediation of the brain, though as seen above, reflexes occur with the centers in the brain, as well.

For a reflex act to occur, the so-called "reflex arc" must be intact.

Reflex Arc.—A reflex arc consists of a receiving neuron to which some stimulus comes *via* the sensory fibers in a cranial or spinal nerve; the association of the branches of this neuron with the branches of a motor neuron, from which a message goes out through a cranial or spinal nerve to the periphery. If all the parts of this arc are intact, a reflex can occur, but if any part is impaired, the reflex is lacking. Not only may this reflex affect a voluntary muscle, but it may also influence the vasomotor and other nerves of the sympathetic system. The number of reflex actions that occur through the spinal cord is very large. Certain tracts in the cord seem to be devoted to these actions. (See page 240.)

The reflex from various muscles may be obtained by a quick blow on their tendons.

Several superficial reflexes that form a part of a routine physical examination may be noted.

Knee-jerk or Patellar Tendon Reflex.—Upon giving a quick blow to the ligamentum patellæ, between the patella and the tubercle of the tibia, with the knee relaxed in a flexed position, there occurs a spasmodic extension of the leg, or a contraction of the quadriceps extensor muscle.

This reflex is present in health, but may vary in degree. If any part of the *arc*, sensory or motor is diseased no reflex occurs. In infantile paralysis and locomotor ataxia it is absent.

Ankle Clonus.—Pressing upon the sole of the foot so as to flex the ankle suddenly and to vigorously stretch the gastrocnemius and the tendo Achillis, there results a rapid and rhythmic extension of the foot. This reflex is not present in health.

Heart Reflex.—Upon striking the spine of the seventh cervical vertebra several light blows, there is an increase in the tone of the heart muscle, as well as in those of the bloodvessels and hollow viscera. (Abrams.)

Special Centers.—Through the reflexes, certain centers in the cord regulate many acts, as defecation, micturition, etc. Through stimulation of various parts of the spinal cord and the mediation of the rami communicantes, the involuntary muscles of various organs as the heart, stomach, intestines and bloodvessels may be made to contract or relax.

Coördination and Automatic Action.—Certain voluntary actions, such as walking, writing, etc., by many repetitions become so entirely familiar, the cord attends to their performance without the mediation of the brain.

THE CEREBROSPINAL NERVES AND PLEXI.

Having considered the cranial and spinal centers, it remains to discuss the branches of each which carry the messages to and fro. Those from the brain are the cranial nerves, and those from the cord are spinal nerves.

All the spinal and some of the cranial nerves are mixed nerves, that is, they contain both motor and sensory fibers.

The spinal nerves arise by two roots from the cord. The anterior or ventral root is motor, several bundles of axones coming from the motor cells in the anterior horns of gray matter.

The posterior or dorsal root is sensory, with a ganglion on it. It comes from the posterior horn of the cord. The ganglion on the root contains the cells, from which two processes arise, one going back to the cord, the other out to help form the spinal nerve. The two roots unite into one trunk that passes out through the intervertebral foramen. (Fig. 216.)

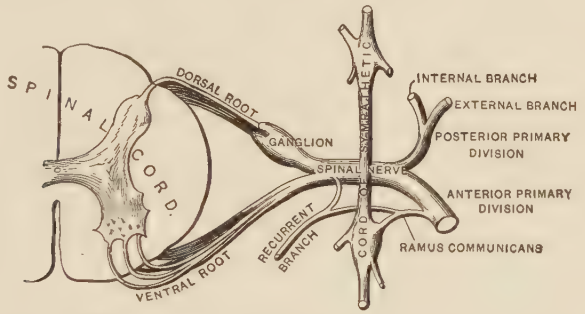


FIG. 216.—Plan of the constitution of a spinal nerve. (Keiller.)

Just after leaving the spinal canal, a recurrent branch is sent back. It receives a branch from the sympathetic and goes into the spinal canal to supply the meninges and bloodvessels. The spinal nerves divide into anterior and posterior primary divisions, the posterior division later dividing into internal and external branches. The anterior division sends a branch, the ramus communicantes, to connect with the neighboring ganglia of the sympathetic.

THE SPINAL NERVES.

There are 31 pairs of spinal nerves, 8 cervical, 12 thoracic, 5 lumbar, 5 sacral and 1 coccygeal. The first cervical nerve comes from the medulla, and passes out of the canal above the atlas. The eighth cervical passes between the seventh cervical and the first thoracic vertebræ. The first 7 cervical nerves are named from

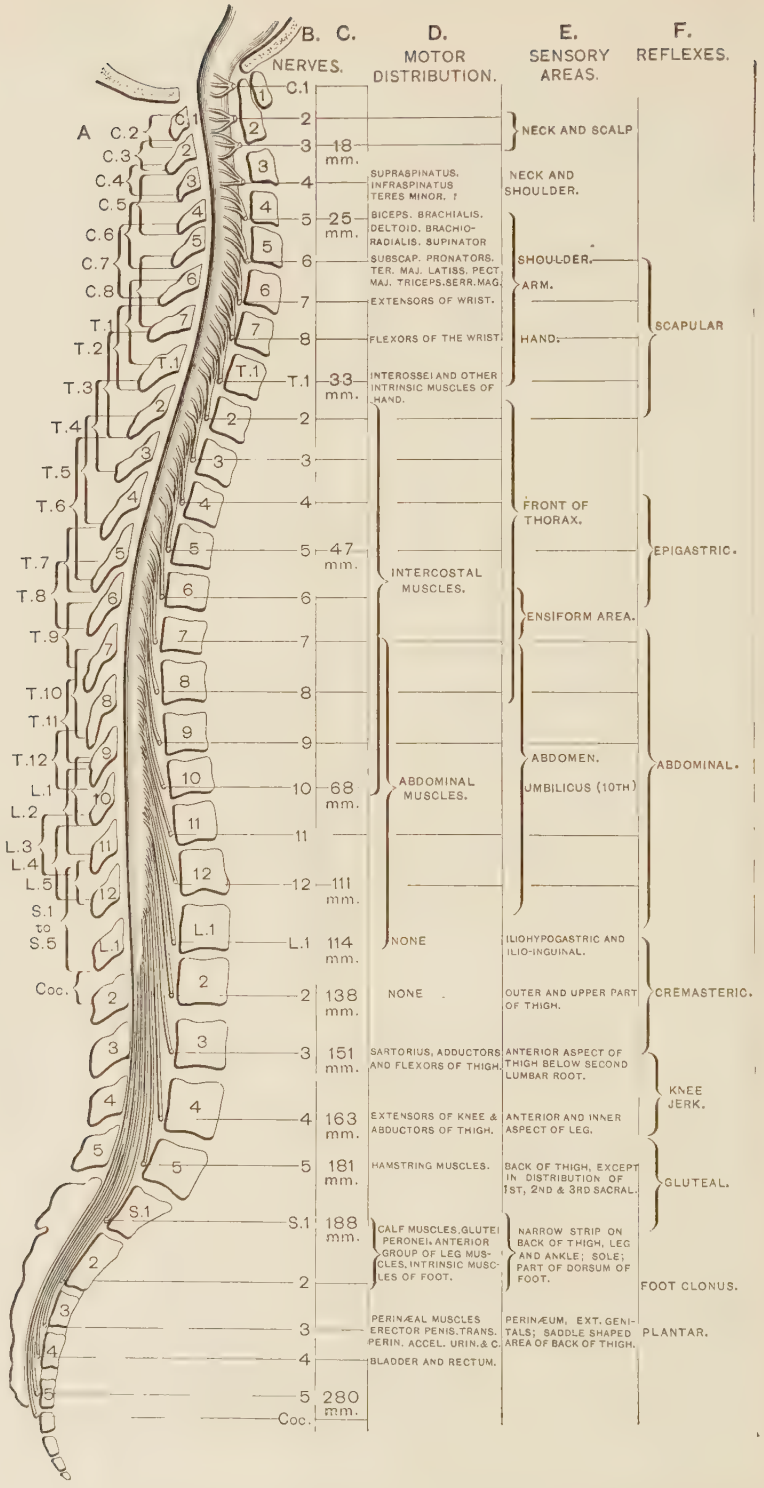


FIG. 217.—Topography and distribution of the spinal nerve roots. (Gerrish.)

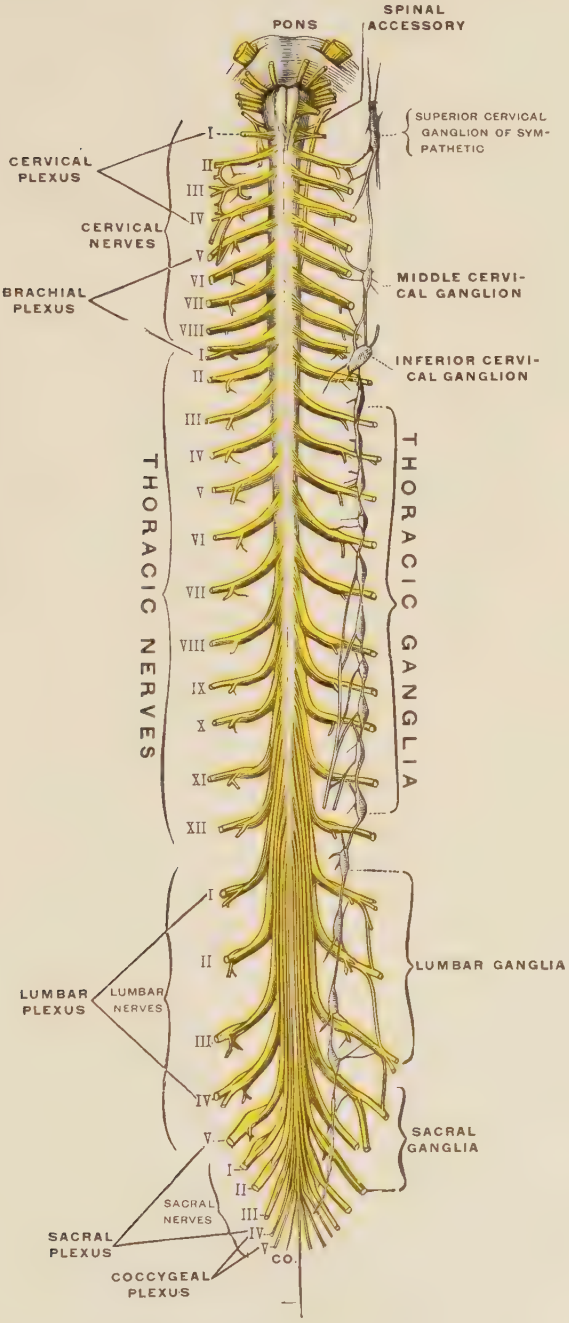


FIG. 218.—Anterior surface of the spinal cord, showing the spinal nerves and their connections with the sympathetic trunk on one side. (Testut.)

the vertebra below them, while the thoracic, lumbar and sacral nerves are named from the vertebra above them.

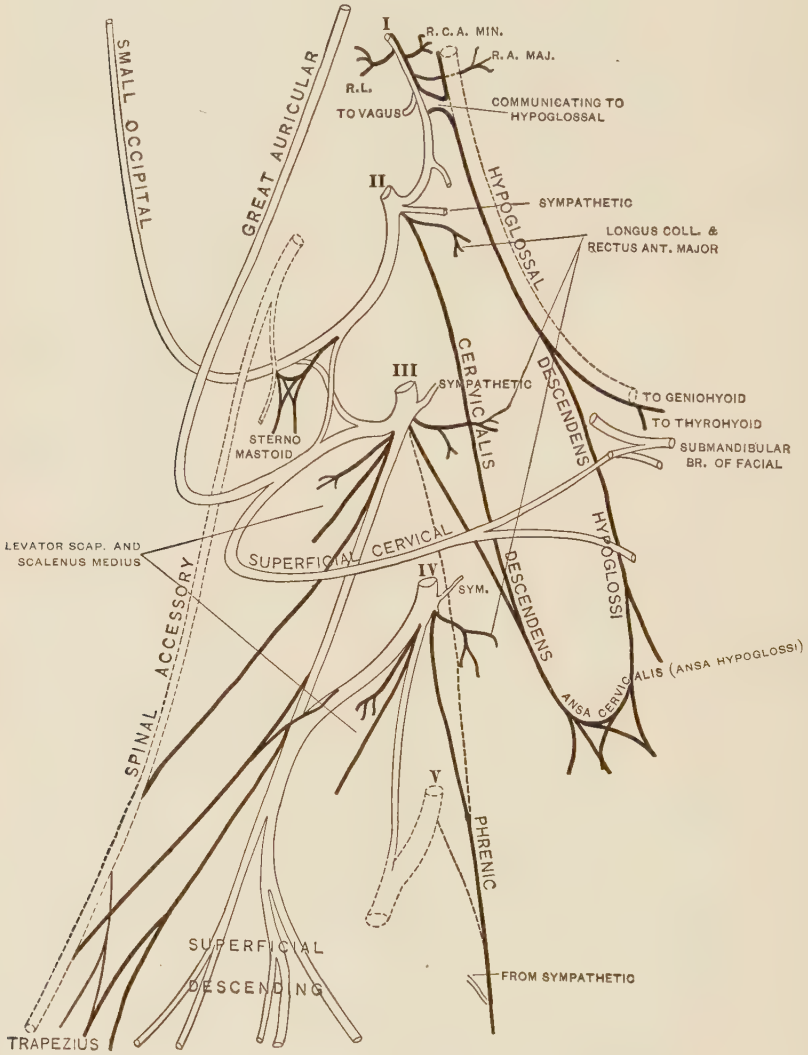


FIG. 219.—Plan of cervical plexus. (Gerrish.)

The dorsal primary divisions of the spinal nerves supply the skin on the back of the head, neck, trunk and gluteal regions, and the muscles that act directly upon the spinal column. These dorsal (primary division) nerves divide into internal and external branches, but they are smaller than those that form the ventral division.

The nerves of the ventral primary division are joined by rami communicantes from the neighboring sympathetic ganglia, by which the structures supplied by the sympathetics may be reflexly affected through stimulation of the spinal nerves (Fig. 217).

In the thoracic region, the ventral division supplies the intercostal muscles, as the intercostal nerves.

Elsewhere, they form plexi, from which the nerves to the periphery start. (Fig. 218.)

There are four plexi, the cervical, the brachial, the lumbar, and the sacral.

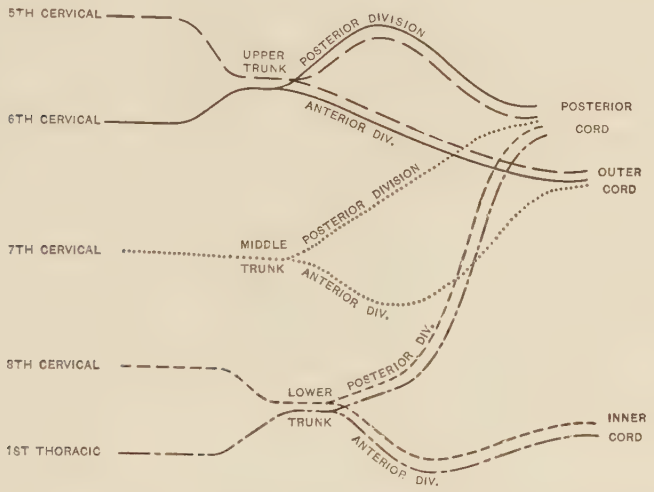


FIG. 220.—Diagram to show the component spinal nerves in the peripheral branches of the brachial plexus.

The Cervical Plexus.—This is an intricate combination from the first four cervical nerves. The parts supplied are the muscles about the head and neck, the trapezius, levator scapulæ, scalenus medius, and the sterno-mastoid. One long nerve, the phrenic, supplies the diaphragm. The nerve on the right side supplying the under surface while that on the left supplies the upper surface of the muscle. (Fig. 219.)

The Brachial Plexus.—This is formed from the fifth, sixth, seventh and eighth cervical, and the first thoracic nerves, with branches from the fourth cervical and the second thoracic. These nerves, by their union before breaking up into terminal branches, provide fibers from most of the five segments for each terminal branch. This association is important in bringing about the orderly movements of the muscles of the upper extremity. Reference to the diagram (Fig. 220), will show the fifth and sixth cervical nerves

uniting to form the upper trunk; the seventh cervical forming the middle trunk, and the eighth cervical and first thoracic forming the

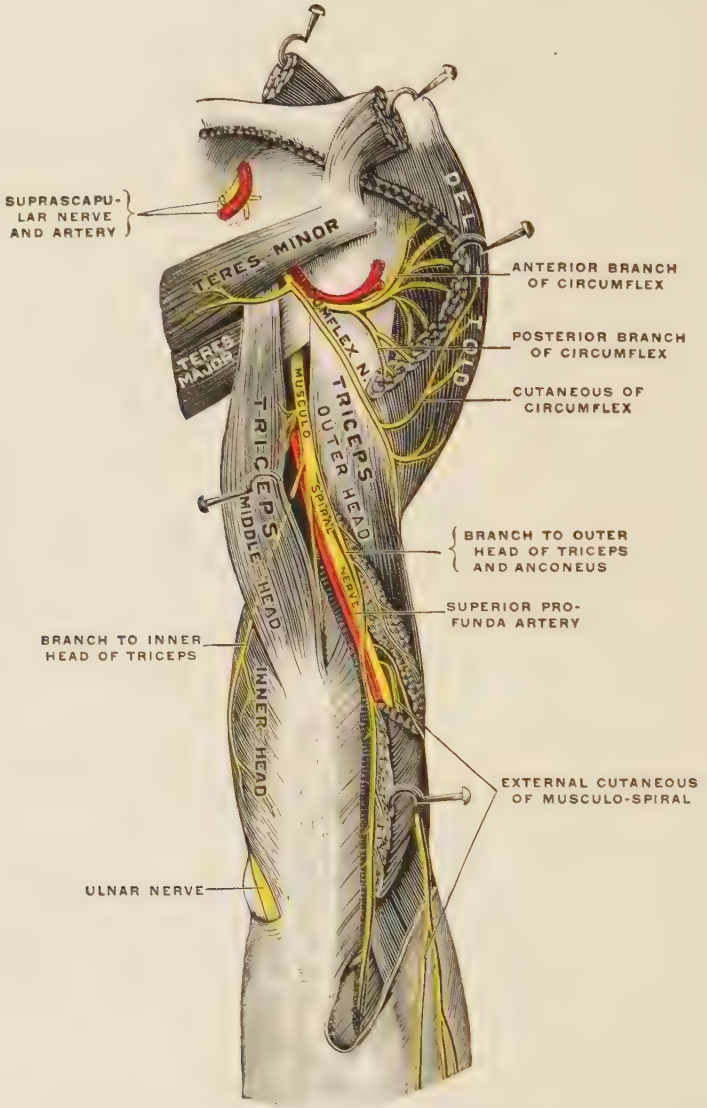


FIG. 221.—Musculo-spiral and circumflex nerves of right side. (Testut.)

lower trunk. Each trunk then divides into anterior and posterior branches. The anterior branches of the upper and middle trunks form the outer cord. The anterior division of the lower trunk forms

the inner cord, while the posterior divisions of all three trunks form the posterior cord. (Figs. 220 and 222.)

The outer cord divides into the musculocutaneous and the outer head of the median; the inner cord into the inner head of the median, the ulnar, the internal cutaneous and the lesser internal cutaneous; the posterior cord into the circumflex and the musculospiral. Other nerves are given off to the rhomboidii and the subclavian muscles. The suprascapular nerve to the supraspinatus and the infraspinatus; the posterior thoracic nerve to the serratus magnus; the external and internal anterior thoracic nerve to the pectoralis major and minor muscles; and the long subscapular nerve to the

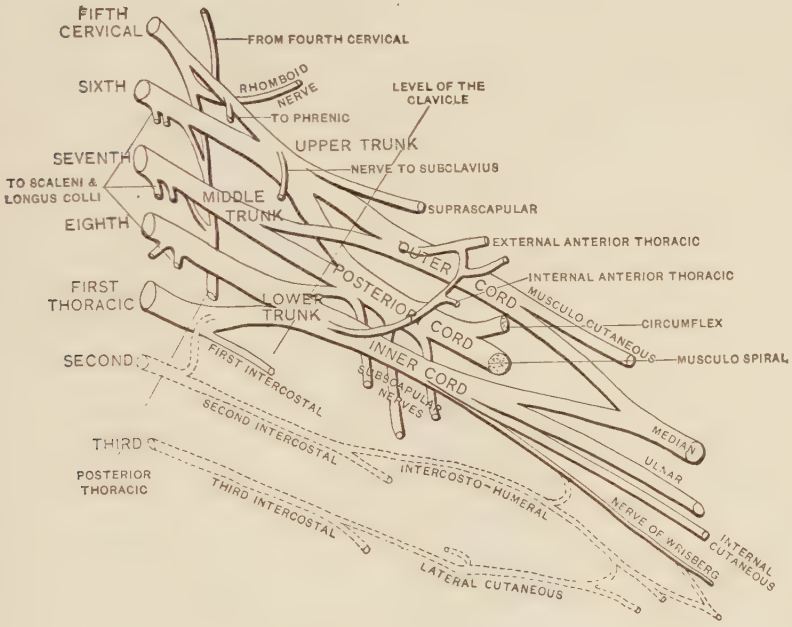


FIG. 222.—Plan of brachial plexus. (Gerrish.)

latissimus dorsi muscles. The *musculocutaneous* nerve supplies the coracobrachialis, the biceps and the brachialis muscles. The *median* nerve passes down on the inner side of the arm between the biceps and triceps muscle, and then passes down the middle of the front of the forearm, supplying all the muscles on the front of the forearm (except the flexor carpi ulnaris and a part of the flexor profundus digitorum), and the short muscles of the thumb that are on the radial side of the flexor longus pollicis.

A deep branch of the median is the *anterior interosseous*. Branches are sent to the skin over the muscles supplied and to the joints those muscles move.

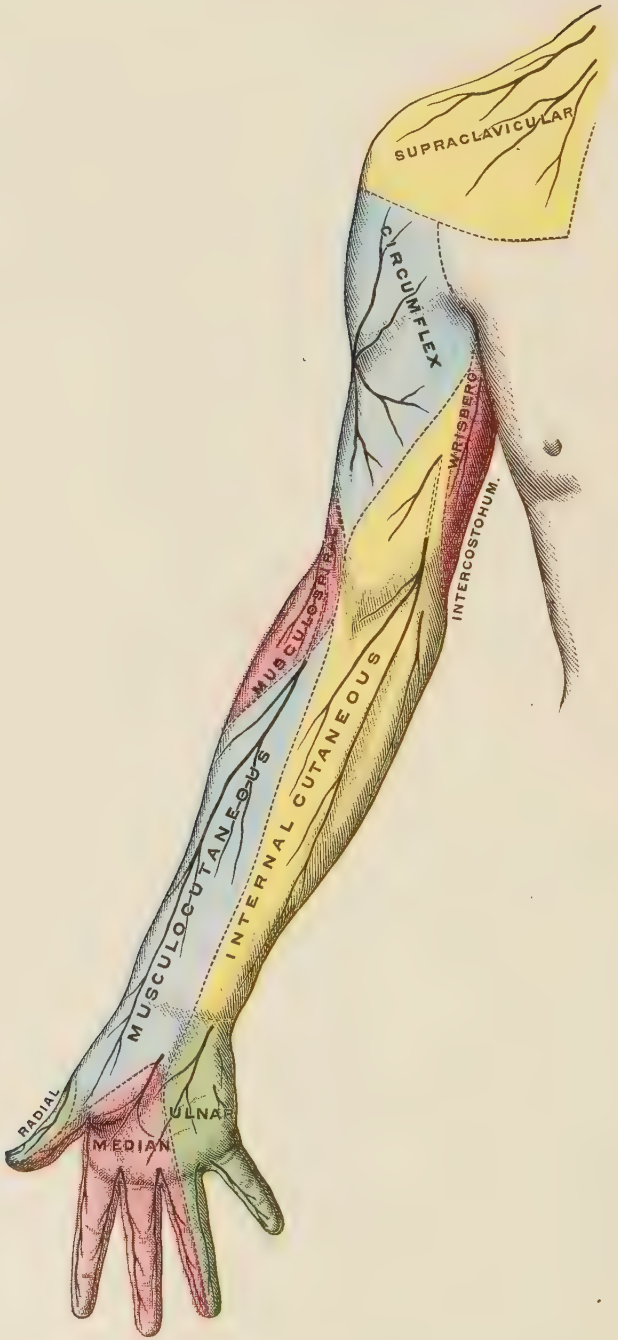


FIG. 223.—Cutaneous nerves of the upper limb, ventral aspect. (Keiller.)

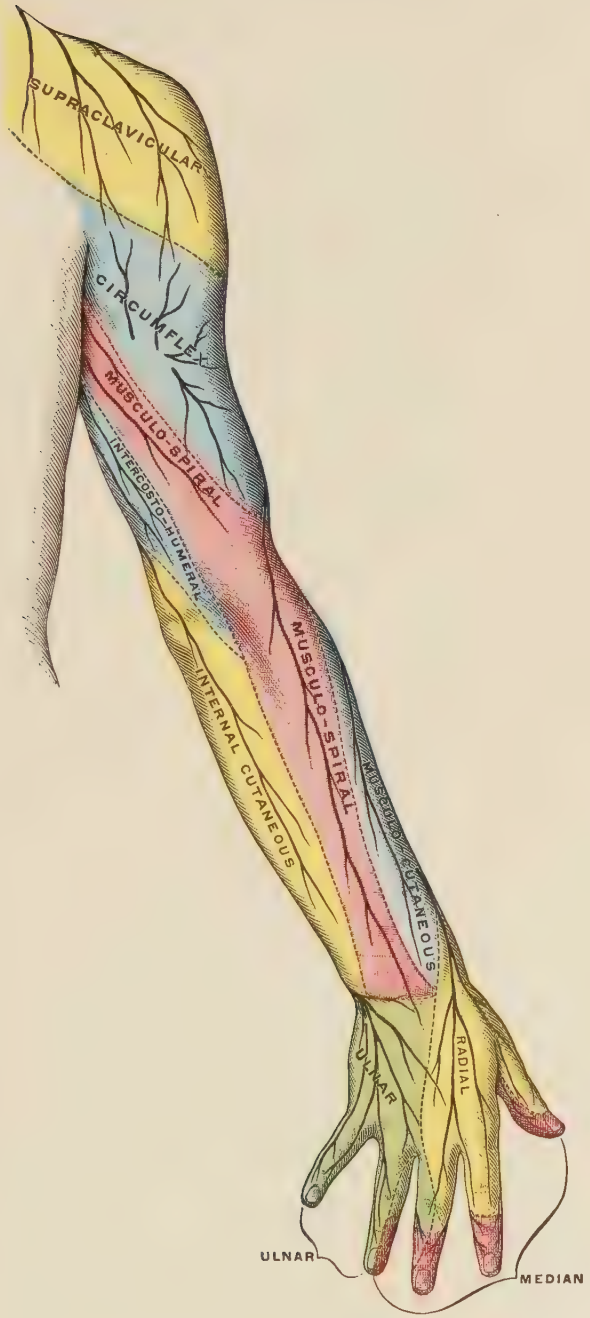


Fig. 224.—Cutaneous nerves of the upper limb, dorsal aspect. (Keiller.)

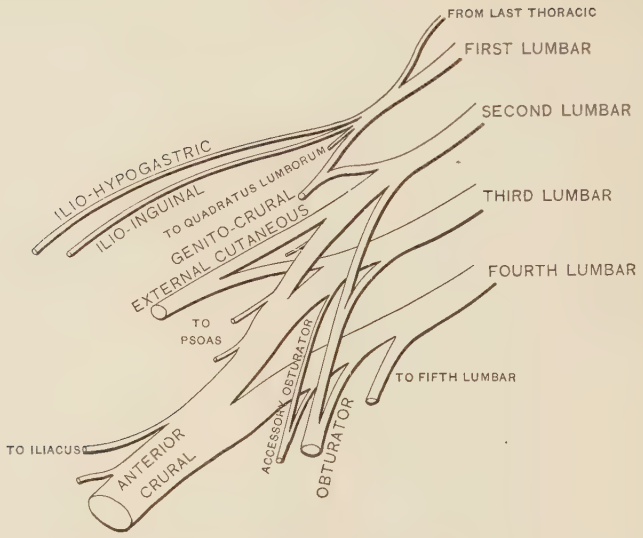


Fig. 225.—Plan of lumbar plexus. (Keiller.)

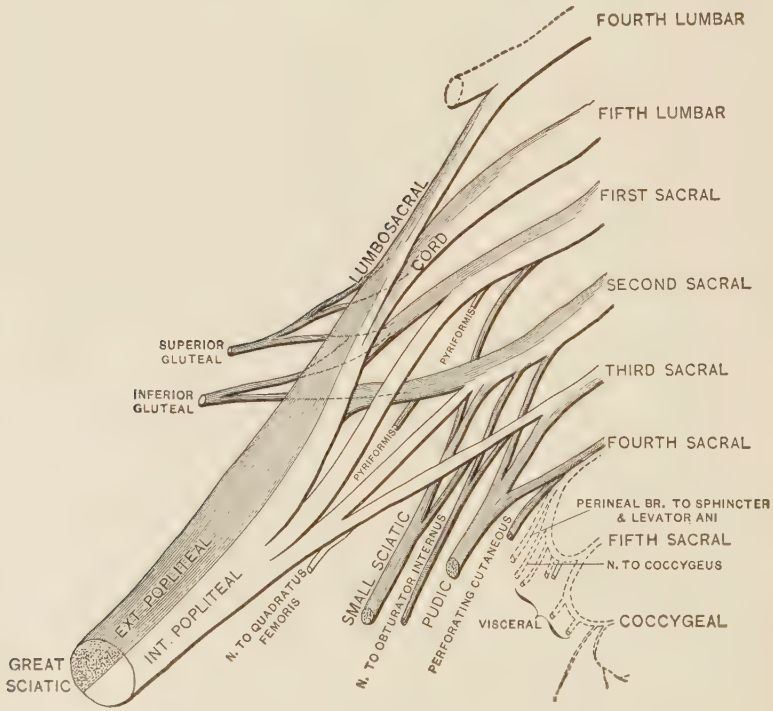


Fig. 226.—Plan of sacral plexus. (Gerrish.)

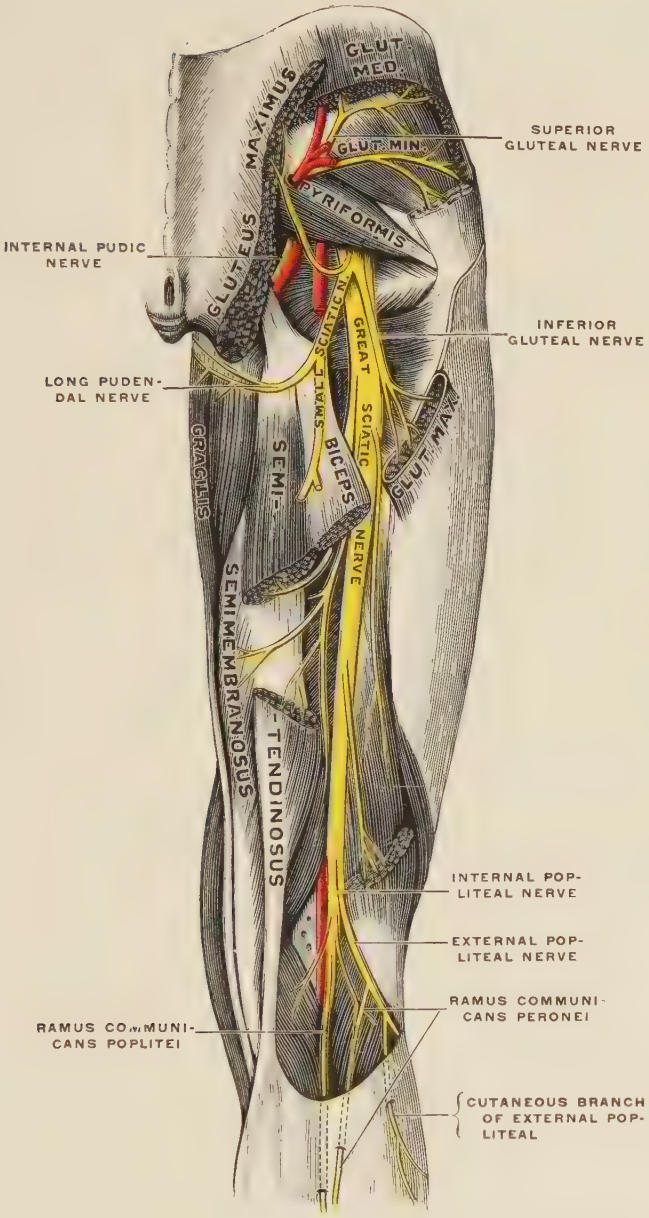


FIG. 227.—Deep nerves of buttocks and back of thigh. (Testut.)

The *ulnar* nerve passes down the inner side of the arm, then between the internal condyle and the olecranon process, and into the forearm. It supplies the flexor carpi ulnaris and the half of the flexor profundus digitorum muscles.

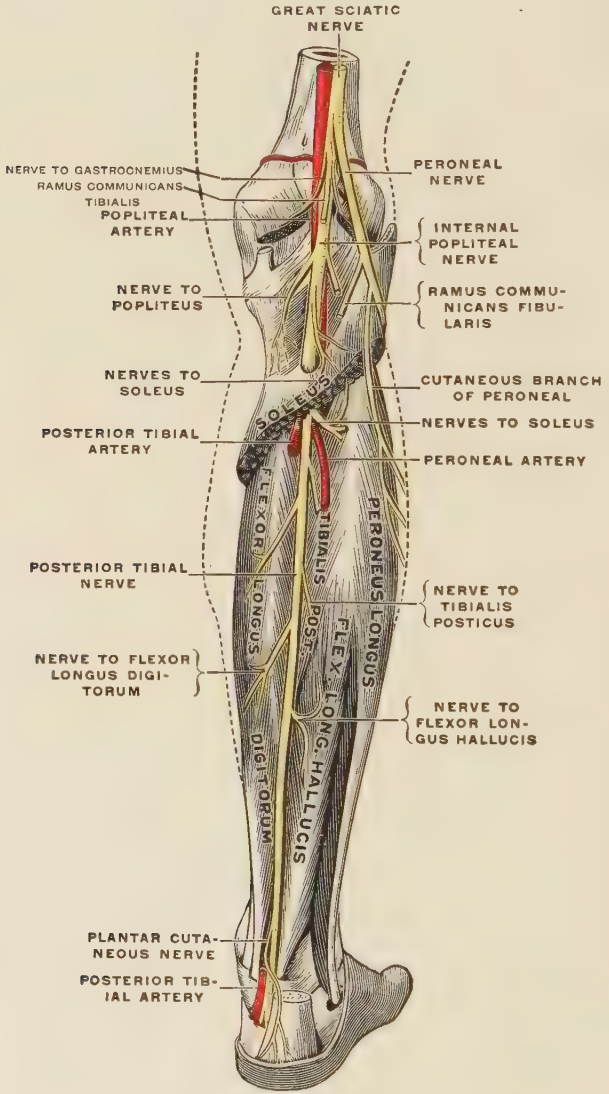


FIG. 228.—Deep nerves of the back of the leg. (Testut.)

The *circumflex* nerve supplies the deltoideus muscle and the shoulder-joint.

The *musculospiral* nerve descends diagonally across the back of the arm, and at the elbow divides into the *radial* and *posterior interosseous*. This nerve, with the two terminal branches supplies *all* the extensor muscles of the arm, forearm and hand. Fig. 221. The distribution of the nerves of this plexus to the skin is observed in Figs. 223 and 224.

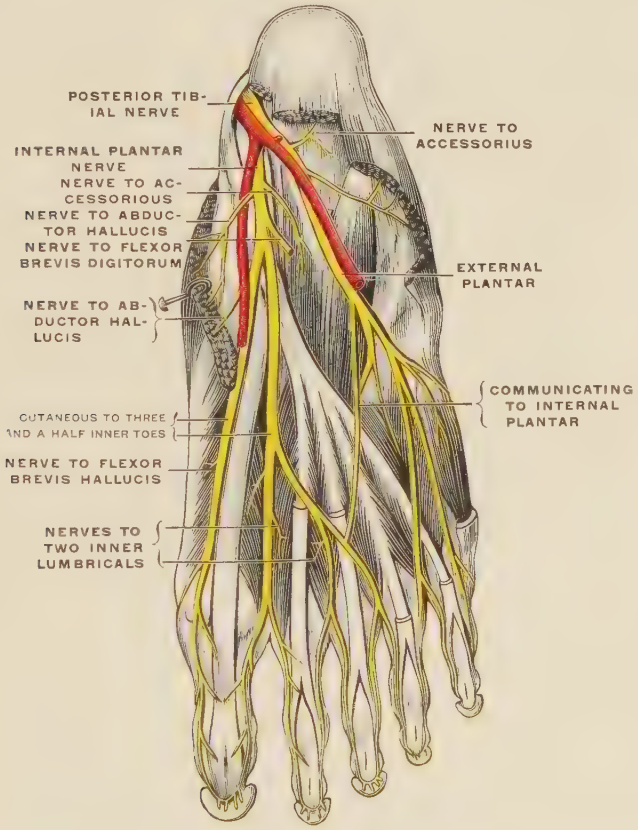

POSTERIOR TIBIAL NERVE
INTERNAL PLANTAR NERVE
NERVE TO ACCESSORIUS
NERVE TO ABDUCTOR HALLUCIS
NERVE TO FLEXOR BREVIS DIGITORUM
NERVE TO ABDUCTOR HALLUCIS
CUTANEOUS TO THREE AND A HALF INNER TOES
NERVE TO FLEXOR BREVIS HALLUCIS
NERVES TO TWO INNER LUMBRICALS
NERVE TO ACCESSORIUS
EXTERNAL PLANTAR
COMMUNICATING TO INTERNAL PLANTAR

FIG. 229.—Plantar nerves. (Testut.)

The Lumbar Plexus.—This is formed from the first, second and third lumbar nerves, with a part of the twelfth thoracic and the fourth lumbar. It is embedded in the psoas magnus muscle. (Fig. 225.) Branches from the plexus supply the muscles on the front and inner side of the thigh, the abdominal wall and the reproductive organs.

Among the principal branches are the *iliohypogastric* and the *ilioinguinal* which go to the abdominal wall muscles.

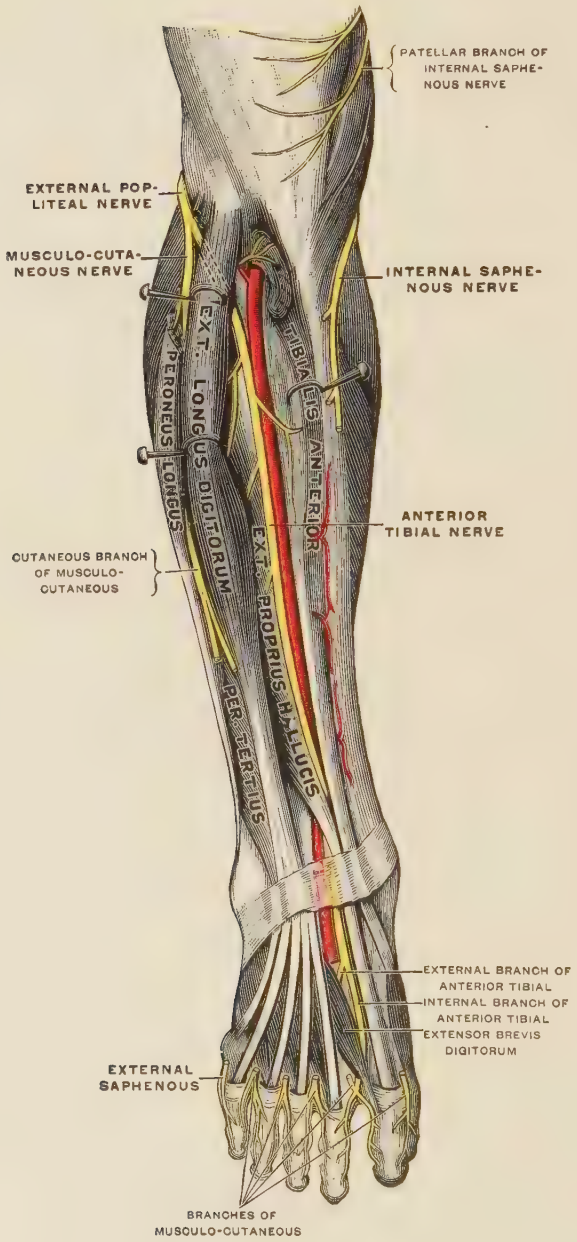


FIG. 230.—Deep nerves of the front of the leg. (Testut.)

The *anterior crural* nerve supplies the iliacus, the pectineus, the rectus femoris, the vasti muscles and the sartorius.

The *obturator* nerve supplies the adductor muscles, obturator internus and externus, besides the hip-joint.

It may be taken for granted that a nerve that supplies a muscle also sends a branch to the joint that muscle moves and to the skin over both. (Hilton.)

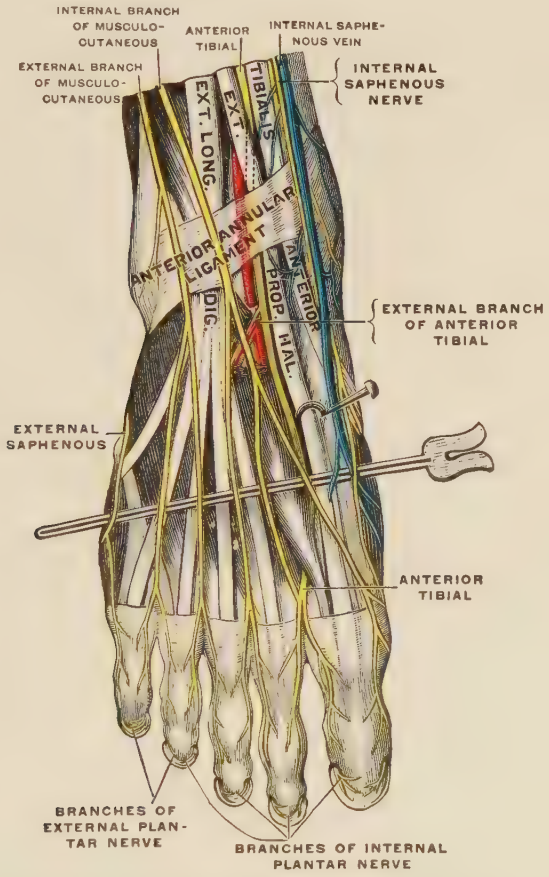


FIG. 231.—Nerves of the dorsum of the foot. (Testut.)

The Sacral Plexus.—This is formed by the part of the fourth lumbar, the fifth lumbar and the first four sacral with branches from the fifth sacral and the coccygeal. (Fig. 226.)

The branches of this plexus divide into anterior and posterior divisions. The posterior set arises from the back of the plexus and supply the extensor aspect of the lower extremity. (They are shaded in the diagram.)

The anterior set arises from the front of the plexus and supplies the flexor muscles of the lower extremity.

The most noticeable branch of this plexus is the *great sciatic*, a large trunk that passes out of the pelvis to the back of the thigh. Branches are given off to the semitendinosus, the semimembranosus, adductor magnus and biceps femoris muscles.

The nerve runs deep in the muscles of the thigh and above the knee divides into the *internal* and *external popliteal* nerves. (Fig. 227.)

The *internal popliteal* passes down as far as the lower border of the popliteus muscle where it becomes the *posterior tibial*. From this, muscular, articular and cutaneous branches are given off. The *posterior tibial* divides into the *internal* and *external plantar* nerves at the ankle. (Figs. 228 and 229.)

The *external popliteal* passes down on the outer side of the leg and divides into the *musculocutaneous* and the *anterior tibial*. Figs. 230 and 231.)

By a study of these illustrations it will be seen that the sciatic nerve supplies the flexor muscles of the thigh and all the muscles of the leg and foot, with the skin and joints thereof.

QUESTIONS.

Name the coverings of the brain and spinal cord.
Of what use is the cerebrospinal fluid?
Name the divisions of the brain.
Compare the functions of the cerebrum and cerebellum.
What is meant by "motor areas" of the cortex?
What are afferent nerves?
What is a "reflex"?
Describe "unconditional reflexes."
What structures are necessary to a reflex action?
In what part of the brain is the "respiratory center"?
Describe the gray matter of the spinal cord.
How is a spinal nerve formed?
In what direction do motor influences pass in the spinal cord and nerves?
What is meant by "column" in the white matter of the cord?
Name the functions of the spinal cord.
What are "rami communicantes"?
What general region receives its motor supply from the brachial plexus?
From what plexus does the innervation of the diaphragm come?
What is the principal nerve coming from the sacral plexus, and what muscles receive motor impulses from it?

NOTE.—While the nervous system, physiologically, is an indivisible unit, for the sake of rendering it a little more easily comprehensible, the portion especially concerned with the voluntary muscles is placed in the chapter immediately following that subject.

The consideration of the sympathetic or autonomic portion is placed in a new chapter immediately following the discussion of the organs which are controlled through those nerves.

CHAPTER VIII.

THE CRANIAL NERVES AND THE ORGANS OF SPECIAL SENSE.

THE CRANIAL NERVES.

From the under surface of the brain, 12 pairs of nerves emerge to be distributed to the following structures. They are indicated by number as well as having definite names (Fig. 206). Of the 12, the first and second contain only afferent fibers; third, fourth and sixth have efferent fibers only; the fifth, ninth and tenth have both afferent and efferent fibers; the seventh, eleventh and twelfth only efferent, and the eighth only afferent fibers.

First pair. *Olfactory,* or nerve of smell is distributed to the upper part of the nasal cavity.

Second pair. *Optic,* or nerve of sight, is distributed to the eyeball as the retina.

Third pair. *Oculomotor,* is distributed to the eyeball muscles, with the exception of the external rectus and the superior oblique.

Fourth pair. *Trochlear,* goes to the superior oblique muscle of the eyeball, with motor impulses.

Fifth pair. *Trifacial,* supplying the front of the scalp, the external ear, the cheek, teeth, gums and front of tongue with sensation, and the muscles of mastication with motor impulses.

Sixth pair. *Abducent,* a motor nerve to the external rectus of the eyeball.

Seventh pair. *Facial,* supplying motor impulses to the superficial muscles of the face and some of those of the throat.

Eighth pair. *Auditory,* the nerve of hearing and equilibrium, distributed to the labyrinth of the internal ear.

Ninth pair. *Glossopharyngeal,* the nerve of taste, distributed to the tongue, with fibers of ordinary sensation and some motor fibers to the tongue and pharynx.

Tenth pair. *Vagus* or *Pneumogastric* nerve has a very extensive distribution, passing from the base of the brain, through the neck (under the sterno-cleido-mastoid muscle), the thorax, the diaphragm into the abdomen. It is partly sensory, partly motor, partly cerebrospinal, partly autonomic.

It receives branches from the *spinal accessory,* the *facial,* the *hypoglossal* and the first two cervical nerves. These modify its action upon the parts to which it is distributed.

Afferent fibers carry sensations from the mucous membranes of the esophagus, larynx, trachea, lungs, stomach and intestines.

Efferent preganglionic fibers pass by way of sympathetic ganglia to the plain muscle fibers of the esophagus, stomach, intestines, bile duct, bronchial tubes and heart.

Motor fibers go, also, to the striated muscles of the pharynx and larynx, influencing the coördination in swallowing.

The afferent fibers assist in maintaining the automatic functions of respiration, cardiac activity and blood-pressure.

The efferent fibers have an inhibitory effect upon the heart, slowing its rhythm.

Stimulation of the vagus increases vasomotor tone in general.

Eleventh pair. *Spinal Accessory,* sending motor fibers to the trapezius and sterno-mastoid muscles.

Twelfth pair. *Hypoglossal,* the motor nerve of the tongue.

THE ORGANS OF SPECIAL SENSE.

The Optic Nerve and the Eye.—The nerve of sight is the second cranial nerve, the *optic,* which, when spread out on the back of the eyeball is called the *retina.* Visual images received by the eye are carried by the optic nerve to the cortex and give rise to the sensations of sight as modifications of light. The eyeball and its appendages are placed in the orbital fossa, in a bed of fat and areolar tissue. It is not perfectly spherical, having a slight increase in the curvature at the *cornea,* in front, and a slight flattening behind.

The study of an eye removed from its socket shows on the outside a dense white fibrous covering, the *sclerotic.* On the front of this is a clear transparent structure like the crystal of a watch, called the *cornea.*

Inside the fibrous structure is a vascular coat with much dark pigment, the *choroid.* Applied to the back of the sphere, is the spread-out nerve of sight, the *retina.*

Filling the sphere, and keeping it from wrinkling and so interfering with sight, is a transparent, jelly-like mass, the *vitreous.* This keeps the eyeball plumped out, yet elastically firm.

Back of the cornea is the crystalline lens, a bi-convex structure that is perfectly transparent. (Fig. 232.) It is surrounded by a capsule which is tightened by the contraction of the ciliary muscle.

Between the cornea and the lens hangs a curtain with a hole in it, which corresponds in use and appearance with the diaphragm of a camera. The curtain is the *iris,* varying in color with different individuals, and the hole is the pupil, which becomes larger or smaller according to the amount of light thrown into it. The space between the cornea and the iris is the anterior chamber of the eye, which with the posterior chamber contains the aqueous humor, or a watery

material which is refractive. The space back of the iris is the posterior chamber.

The eyelids cover the ball, and attached to their edges are the cilia or lashes. Lining the lids and covering the exposed surface of the eyeball is a mucous membrane, the *conjunctiva.*

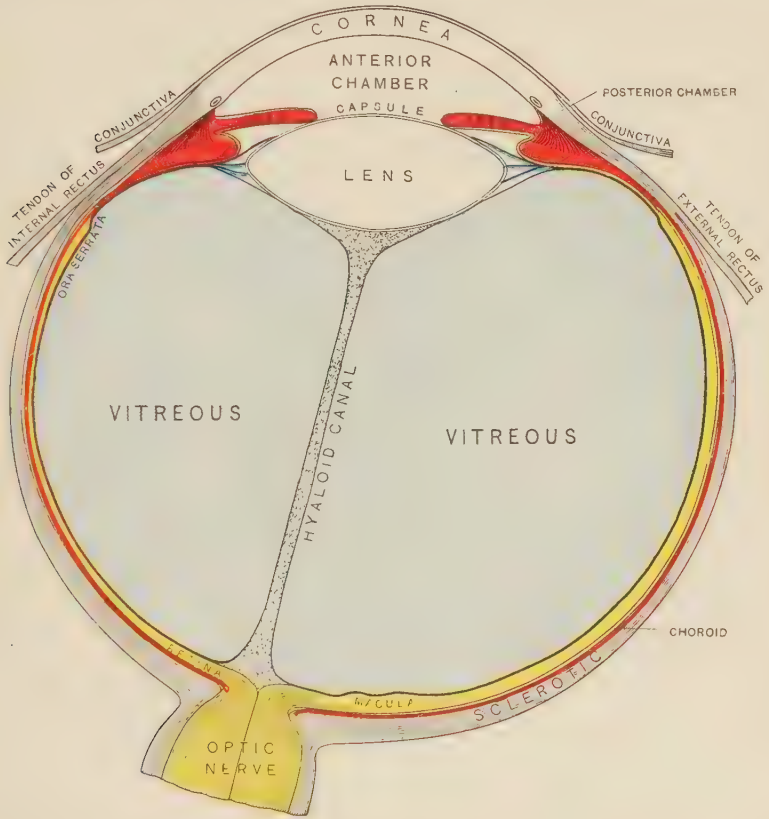


FIG. 232.—The right eye in horizontal section, showing the upper surface of the lower segment. Diagrammatic. (Testut.)

At the inner border is the opening of a tube, that leads into the nasal cavity and carries the tears and any small particles from the surface down into the nose. This is the *lachrymal* duct and the little gland that secretes the tears is the lachrymal gland. The eyes are closed by the contraction of the *orbicularis palpebrarum,* a muscle that surrounds the eye.

Accommodation.—The pupil reacts to light and to distance. The more light there is thrown into the eye, the smaller the pupil becomes. An object brought nearer to the eyes causes the pupil to diminish in size. If it is placed at a greater distance the pupil opens wider.

The normal stimulus of the retina is light, and this is admitted through the pupil, refracted by the cornea, lens, aqueous and vitreous humors. Parallel rays of light coming from an object are refracted so their image falls on the retina in an inverted position, but through experience we have learned to imagine things in their proper position, in spite of the upside-downness of them. (Fig. 233.)

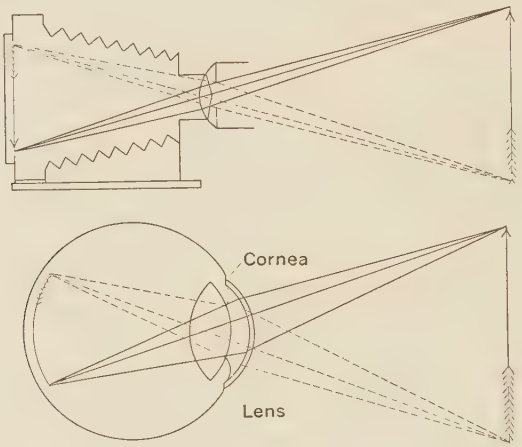


Fig. 233.—Note that in the camera the lens changes the direction of the ray of light, and in the eye the same change is seen twice—once through the lens, and again through the cornea.

In the camera, if nearby objects are to be photographed, the distance between the lens and the sensitive plate is increased and *vice versa*.

In the eye, if accommodation is made for near objects, the distance between cornea and retina is increased.

At 20 feet or more the rays of light coming from objects are practically parallel. From nearer objects, down to 3 inches, the rays become more divergent. In order to have a clear image from such objects the eyes must "accommodate." In this process the eyeballs turn inward and increase in length.

Innumerable theories have been advanced to explain "accommodation." That which claims an increase in the antero-posterior diameter of the lens by the contraction of the ciliary muscle, has been largely accepted despite the observed fact that many who have had the lens removed are able to accommodate. Another theory explains it as due to the increase in the antero-posterior diameter of the eyeball by the action of the superior and inferior oblique muscles.

Six muscles are attached to the eyeball. Four recti—superior, inferior, internal and external—turn it respectively upward, downward, inward and outward. This includes turning the cornea. The superior and inferior obliques form an almost complete belt

around the equator of the eyeball. When they contract the eyeball lengthens. It is, apparently, by their action that the "lensless" eye (probably, too, the normal eye) can accommodate. (Fig. 234.)

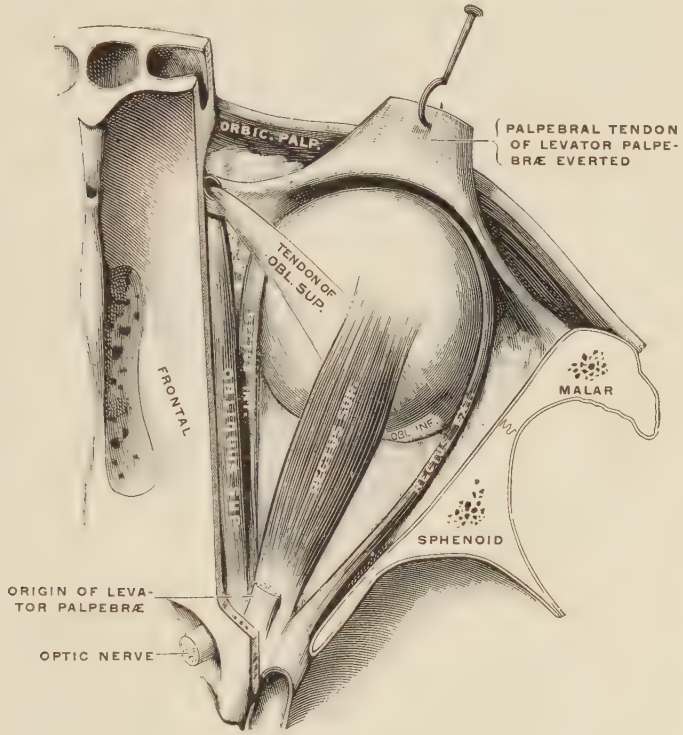


FIG. 234.—Muscles of the right eye, viewed from above. (Testut.)

In a normal *emmetropic* eye the image of an object comes to a focus on the retina. In a long *myopic* eye the image falls in front of the retina. In the short, *hypermetropic* or *presbyopic* eye the image is formed back of the retina. These changes in the length of the eyeball can be produced by strain and relieved by relaxation.

The Auditory Nerve and the Ear.—The organ of hearing is divided into three parts, the external, middle and internal ear.

The External Ear.—The external ear is a flaring cartilaginous structure, which collects the sound waves and focuses them into the external auditory meatus, a tube leading to the partition between the external and middle ear. This tube is the epithelial lined auditory canal in the temporal bone, and contains some cells which secrete cerumen or wax. This wax catches dust and any small insects that attempt to get into the ear. (Fig. 235.)

At the inner end of the meatus is a membrane that separates the external and middle ear. It is the *membrana tympanum.*

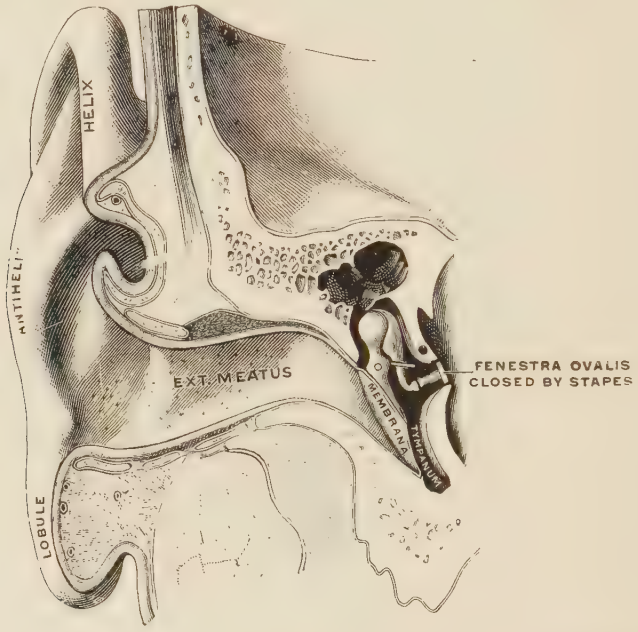


FIG. 235.—Vertical section through the external auditory meatus and tympanum passing in front of the fenestra ovalis. (Testut.)

The Middle Ear.—Back of this membrane is a space, the *tympanum,* which contains three small bones or ossicles, the *malleus, incus* and *stapes.* These are arranged in a series, so the malleus is in contact with the membrana tympanum, and is moved by its vibration; the incus joins the malleus and the stapes. The last, connects the others to the opening between the middle and internal ear, the *fenestra ovalis.*

Sound waves throw the membrana tympanum into vibrations, which the chain of bones transmit to the fenestra ovalis.

Opening into the tympanic cavity is a tube, about $1\frac{1}{2}$ inches long, which extends to the back of the pharynx. This is the Eustachian tube, carrying air from the throat to the middle ear, so as to equalize the pressure within and without the ear, on each side of the membrana tympanum.

The Internal Ear.—The internal ear begins back of the fenestra ovalis, and consists of a labyrinthine sac, lined with a very sensitive membrane, and filled with a fluid in which are some hard particles. This sac is in several parts, the most anterior of which is the *sacculc.* From it extends a long coiled process, the *cochlea.*

The posterior sac is the *utricle*, from which three *semicircular canals* emerge, going in three different directions. The function of these has to do with maintaining equilibrium.

The auditory nerve is distributed upon an area of the utricle, and stimuli reach it by the waves of sound transmitted through the membrana tympanum, the chain of bones, and the fluid in the sac, finally reaching the auditory center in the brain as sound. Neuro-epithelial cells with waving cilia are concerned in the final step.

The Gustatory Nerve and the Tongue.—The tongue is the principal organ of taste and of articulate speech, helping in mastication and deglutition. It is highly sensitive to touch, heat and cold.

It is an index of the body health, showing the degree of elimination that is going on. It is occasionally a means of diagnosis, as its appearance is sometimes characteristic of special conditions. The tongue consists of a muscle, the *lingualis*, which has a median raphé, and is attached to the hyoid bone. Associated with it are several others, the genioglossus, the hyoglossus, the styloglossus and the chondroglossus muscles. A large variety of movements are possible to this combination.

The tongue is covered with a mucous membrane, the back part of which contains the "taste buds," or terminals of the gustatory nerve. (Fig. 236.) (See also page 329.)

The Olfactory Nerve and the Nose.—The nose is a prominent part of the face, and is formed mostly of cartilage. The two nasal bones at the upper part, the vomer and the ethmoid forming the septum, serve to support the cartilage.

The openings visible in front are the anterior nares, while those posteriorly which communicate with the pharynx are the posterior nares.

The nasal fossa contains three bodies, the superior, middle and inferior turbinated. The superior body is osseous, but the other two are cartilaginous. These bodies are scroll-shaped, providing a large extent of surface for mucous membrane. (Figs. 237, 238.) Lining the nose, the septum, the turbinated bodies and communicating with the similar lining of the naso-pharynx, the ethmoid cells, etc., is a mucous membrane, rich in bloodvessels. This is the Schneiderian membrane. On that area covering the superior turbinated bodies the olfactory nerve is distributed.

The nose is also a special external organ of respiration, and the intricate convolutions of the interior are to provide a large vascular surface by which the incoming air may be warmed before going into the lungs. (See also page 304.)

Nerves of Touch and General Sensation.—The special organ of the sense of touch is the skin. As the skin will be described in detail in connection with the organs of elimination, no description of it will be given here.

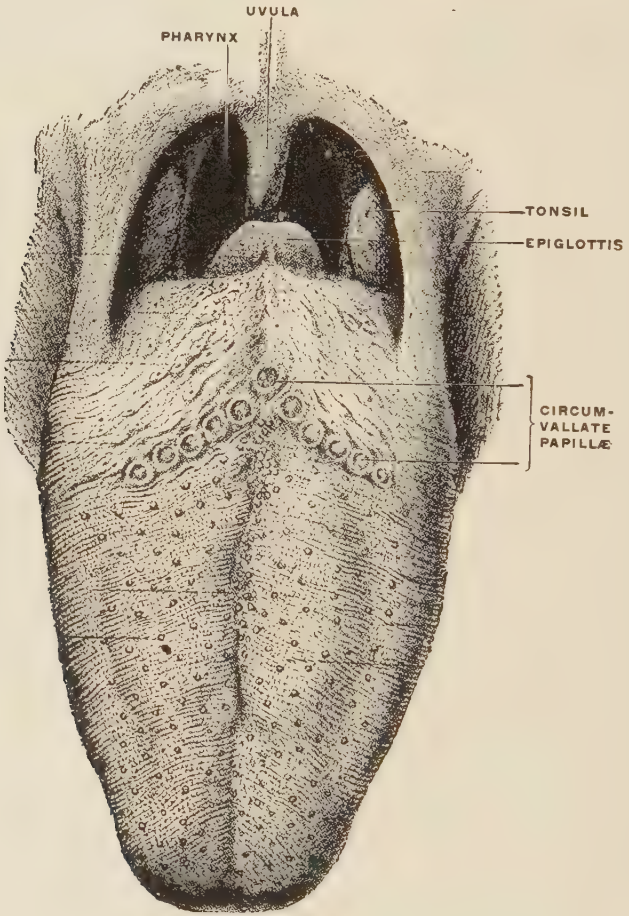


FIG. 236.—Dorsal surface of the tongue. (Testut.)

The muscles, tendons and joints are supplied with sensory nerves from which is developed what is sometimes called the "muscular sense" or the kinesthetic sense, by which we are conscious of the position in space occupied by our members and the movements performed by them, etc. (See page 241.)

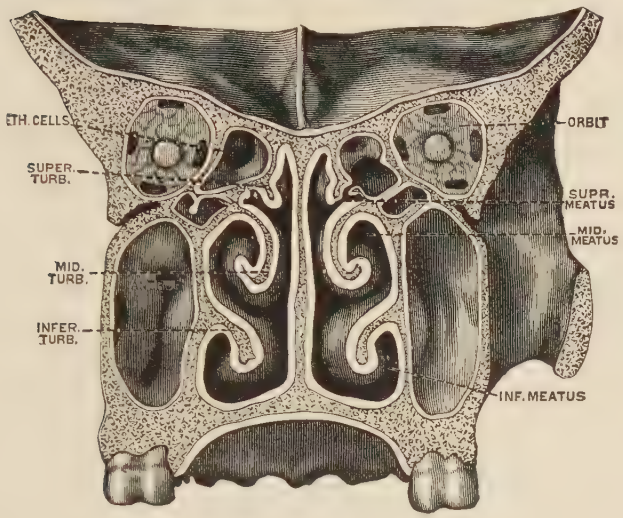


FIG. 237.—Coronal section of nasal fossæ at the plane of the second molar tooth seen from behind. (Hirschfeld.)

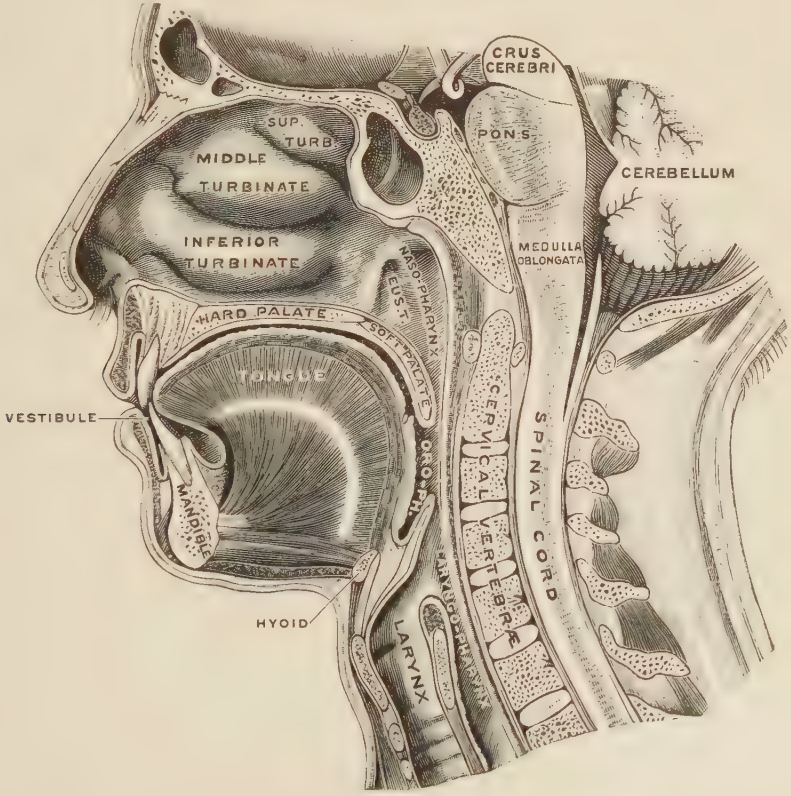


FIG. 238.—Sagittal section of face and neck, showing external wall of right nasal fossa. (Testut.)

QUESTIONS.

Name the parts of the eyeball.

What is the pupil of the eye?

What correction must be made in our conception of images projected on the retina

What function has the Eustachian tube?

Can you tell what symptoms you might have if your semicircular canals were diseased?

How many uses has the tongue?

Of what use are the turbinated bodies?

What is the "kinesthetic sense"?

CHAPTER IX.

THE CIRCULATORY SYSTEM.

The blood in the body is contained in a system of closed tubes, into which two other tubes open. This makes for a continuous flow of blood from one part of the body to another, with varying amounts in the different regions at different times. The life of every part of the body is dependent upon an adequate supply of blood. There must be some way to insure the flow of blood as whatever amount there is in the tubes must answer for all needs.

The organs concerned are the heart, arteries, veins, capillaries and lymphatics. Two pumps, one of them a force pump, the other a suction pump provide the power to keep the blood in motion. The *force pump* is the *heart*. The *suction pump* consists of several mechanisms, not located in any one spot.

THE ANATOMY OF THE HEART.

The heart is a hollow muscular organ, forming the central reservoir for the blood, and a pump. It consists of four chambers, two on each side. In shape it is bluntly conical, with the apex about the fifth intercostal space. The base is on the level of the upper border of the third rib. It extends about $\frac{1}{2}$ inch to the right of the sternum, and approximately $3\frac{1}{2}$ inches to the left of the mid-sternal line. (Fig. 239.)

The Pericardium.—The walls of the heart are made of cardiac muscle. It is covered by a layer of serous membrane which is doubled back to form a pouch-like structure. This sac has an outer fibrous investment which is attached to the diaphragm below, to the cervical fascia above, and to the pleuræ covering the lungs on each side. This covering is the *pericardium*. It is applied loosely to the heart, and invests part of the large vessels leaving the heart. A serous fluid is secreted which serves to prevent friction, as the heart swings back and forth.

The chambers of the heart are two ventricles and two auricles. The auricles are placed above the ventricles, and it is practically true to say there are two hearts, the right and the left, as they do not communicate with each other, though the auricles open into their corresponding ventricles.

Leading out from the right ventricle is a large tube, the pulmonary artery, while the aorta leads out from the left ventricle. The

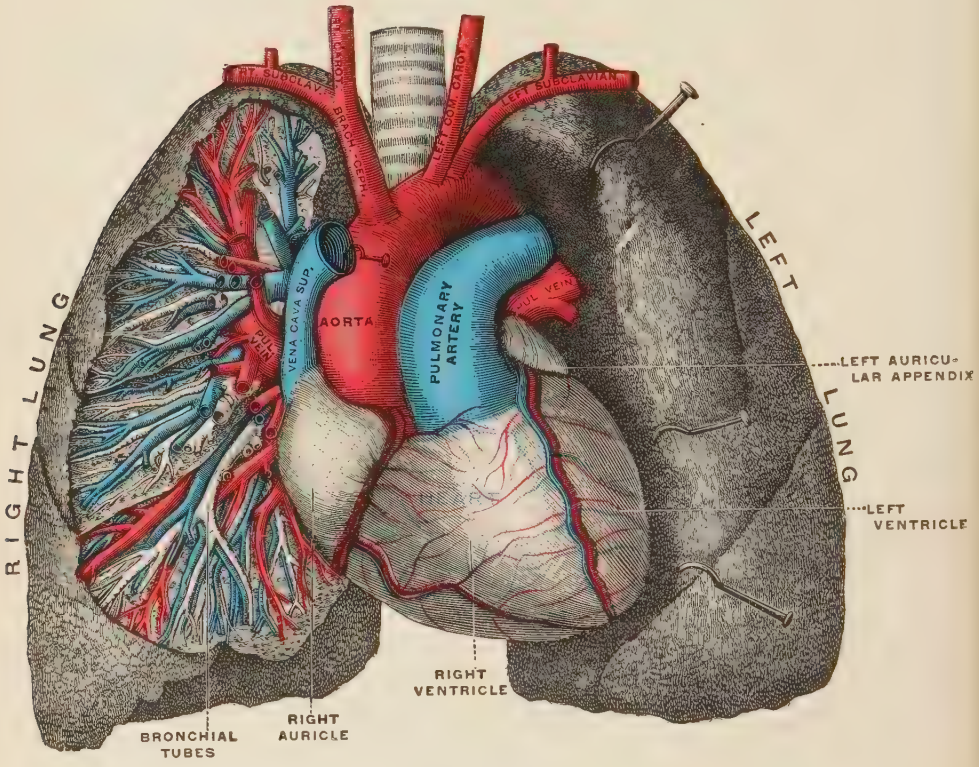


FIG. 239.—The pulmonary artery and aorta. The front part of the right lung has been removed, and the pulmonary vessels and the bronchial tubes are thus exposed. (Testut.)

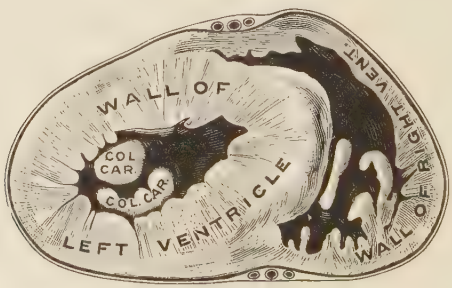


FIG. 240.—Cross-section through both ventricles, showing the shape of their cavities and the relative thickness of their walls. (Testut.)

right auricle has opening into it two large tubes, the superior and the inferior vena cavæ. The left auricle has opening into it four pulmonary veins.

There is much difference in the thickness of the walls of the two ventricles, the left having the greater amount of tissue. This is required on account of the greater amount of work done by the left ventricle. (Fig. 240.)

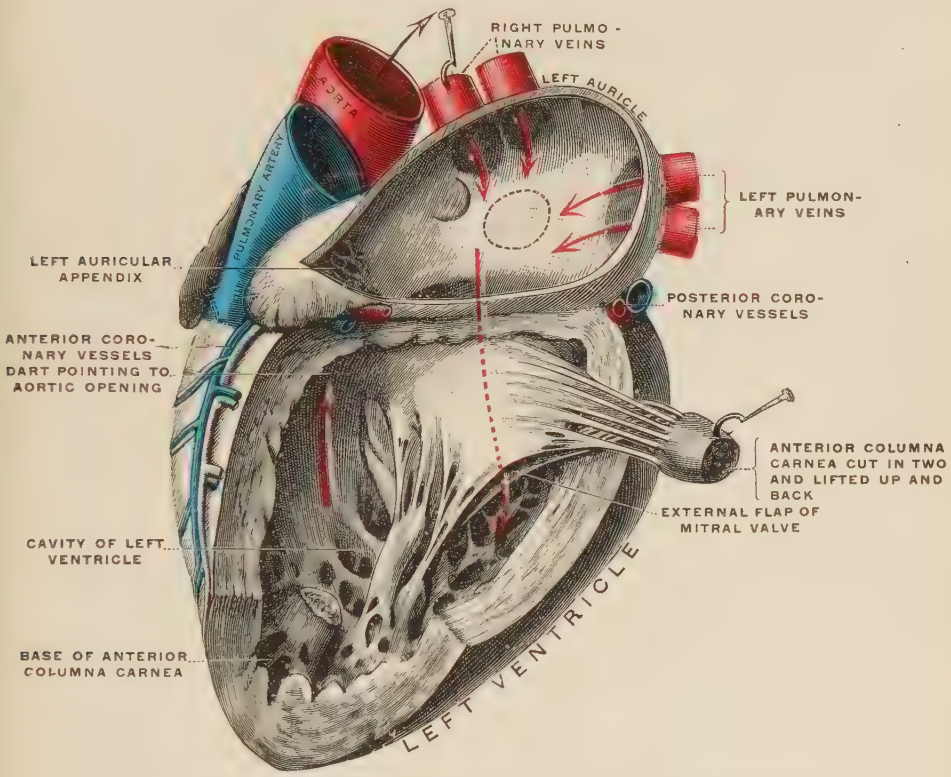

RIGHT PULMONARY VEINS
LEFT AURICLE
AORTA
PULMONARY ARTERY
LEFT PULMONARY VEINS
LEFT AURICULAR APPENDIX
POSTERIOR CORONARY VESSELS
ANTERIOR CORONARY VESSELS DART POINTING TO AORTIC OPENING
ANTERIOR COLUMNA CARNEA CUT IN TWO AND LIFTED UP AND BACK
EXTERNAL FLAP OF MITRAL VALVE
CAVITY OF LEFT VENTRICLE
BASE OF ANTERIOR COLUMNA CARNEA
LEFT VENTRICLE

FIG. 241.—Left auricle and ventricle, the hind wall of each having been removed. (Testut.)

Columnæ Carnæ.—The inner surface of the ventricle presents a series of fleshy projections. These are the columnæ carnæ. (Fig. 241.) They seem like additional supports to the walls.

Valves of the Heart.—The openings between the auricles and ventricles, and those between the heart and its large vessels are closed by movable fibrous valves. These open to let the blood pass through, but close to prevent a backward flow of blood.

On the right side of the heart, the opening between the right auricle and right ventricle is closed by the *tricuspid* valve. On the

left side, the corresponding valve is the *mitral*. The opening between the right ventricle and the pulmonary artery is closed by the pulmonary valve, with the aortic valve in the corresponding position on the left side. (Fig. 242.) Running between the auriculoventricular valves and the columnæ carnæ are delicate fibrous cords, the *chordæ tendineæ*. Lining the cavities and the valves of the heart is a delicate serous membrane, the *endocardium*.

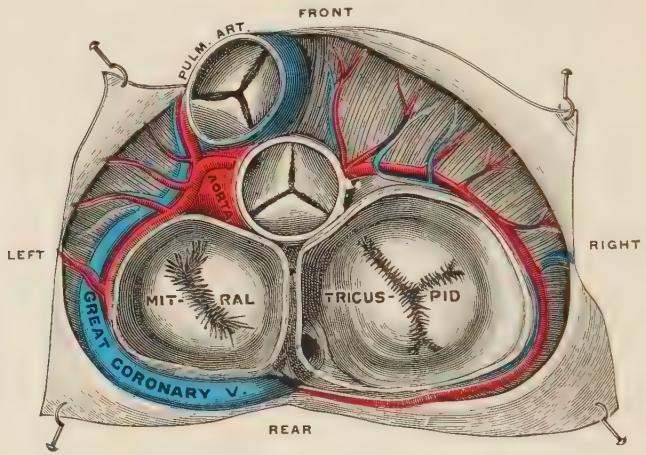


Fig. 242.—Valves of the heart and great arteries, viewed from above, the auricles having been removed. (Testut.)

THE ANATOMY OF THE ARTERIES.

Arteries are the tubes by which the blood is carried *from* the heart. The quality of the blood does not matter, that is, whether it is pure or impure, aërated or unaërated. If the vessel comes from the heart it is an artery.

As the blood leaves the heart with considerable force, the arterial walls must be strong enough to withstand it. As it comes in spurts, the walls must be elastic enough to stretch and afterward recoil, returning to their normal size. The walls must provide for changes in the caliber of the vessel, so it may be made smaller on occasion. And, it must present no obstruction to the flow of blood by reason of roughness of the lining.

To provide for all these contingencies, arteries have three coats, or tunics. On the outer side is a white fibrous layer, with some yellow elastic fibers. The middle coat has plain muscle tissue, with some yellow elastic tissue. The inner coat is an epithelial layer, with a small amount of yellow elastic tissue.

The elasticity of the arterial walls is marked, especially in the larger ones. There is considerable variation in the relative amounts

of fibrous and muscular tissues, the largest arteries having little muscular but much fibrous tissue.

The smaller arteries have more muscular and less fibrous material, while the middle sized arteries have about equal quantities of each.

Divisions of an Artery.—From the heart, two large arteries are given off. These two divide and subdivide, branching in every direction like a tree. (Fig. 243.) As the arteries divide they become smaller, but when the cross-sections of all the branches are considered, the sum total is much more than that of the original trunk. This is widening the bed of the arterial system, and as in any stream under such circumstances, the rate of flow is decreased.

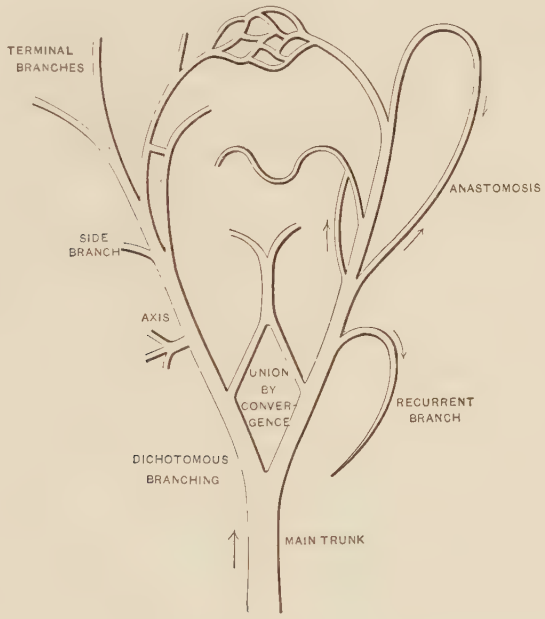


Fig. 243.—Diagram showing the branchings, anastomoses and confluence of arteries. (Gerrish.)

In an artery which supplies an extremity, the trunk which enters the limb sends off branches from the side; it may send a deep or superficial branch that is as large as the original; it will send direct articular branches to the joints and recurrent branches going back to nourish the joint when the direct supply is shut off by muscular contraction or position; it will send off branches to anastomose with the anastomosing branches of other arteries, and send a nutrient artery to the bone. It will also send off small arteries the *vasa vasorum* to nourish the walls of the larger ones.

When arteries have divided and subdivided until they are micro-

scopical in size, they have lost most of the fibrous covering, much of the muscular coat, but have retained all the epithelial tunic. They are then called "arterioles." (Fig. 244.) Arteries lie in a bed of areolar tissue, usually accompanied by the nerve that supplies the same part and the vein that drains it.

FIG. 244.—Diagram of the arrangement of muscle cells in an arteriole. (Gerrish.)

THE ANATOMY OF THE CAPILLARIES.

When every coat of an arteriole is lost except the epithelial, it becomes a *capillary*. The single layer of epithelium forming the wall (Fig. 245), will allow the materials of the blood plasma to pass through it into the spaces around the microscopical cells, and the waste materials in the spaces to pass into the capillary. The length of a capillary is microscopical, and its diameter so small that the red corpuscles can pass through it in single file only. Their size

FIG. 245.—Capillaries, showing the shape and arrangement of the cells which make their wall. (Carpenter.)

varies, those in the lungs being the largest in the body. Those in muscle tissue are placed between the fibers in areolar tissue. (See Fig. 29.) When the capillary acquires a small amount of additional tissue it becomes a venule or venous radicle. This unites with another venule, and these with another, until several have united in a single vessel, which is then a vein. Small veins unite to form larger veins, until finally two trunks, the venæ cavæ, superior and inferior, discharge all the venous blood into the right auricle. The number of veins is greater than that of arteries, so that it is possible

for the veins to contain all the blood in the body, leaving the arteries empty. The rate of flow in the veins being slower than that in the arteries, more room is required to accommodate it. An artery is often accompanied by two veins, the "venæ comites."

THE ANATOMY OF THE VEINS.

The veins are the tubes that carry blood *to* the heart. This holds good regardless of the state of the blood as to aëration. The walls of the veins do not need to withstand the shock of a force pump but they need to be as strong as those of an artery. They lack the stiffness of arterial walls and collapse immediately when emptied, whereas an artery remains patulous even if it is very small. There is considerable variation in the walls of veins. The inner coat is always the same, an epithelial layer, with minute folds in it called valves. These prevent the backward flow of the blood. As it starts backward, it runs in behind the folds of the valves and pushes them open, and thus closes the lumen of the vessel. (Fig. 246.)

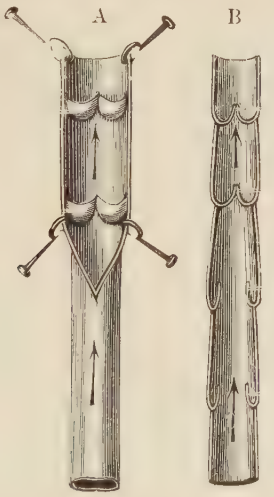


FIG. 246.—Valves of veins. A shows a vein cut open between the segments of two valves. B shows appearance of valves closed and open. (Testut.)

The middle coat of the veins contains but little muscular tissue, but some fibrous material. The outer coat is white and yellow fibrous tissue.

THE ANATOMY OF THE LYMPHATICS, INCLUDING GLANDS. (NODES.)

Lymphatic vessels begin as the open ends of tubes in the spaces around the microscopical cells. These are "stomata" and the

spaces in which they open are variously termed, "perivascular," "intercellular," "juice channels," "juice canals," "lymph spaces."

The lymph radicles unite to form larger tubes, which in turn unite to form still larger tubes, in the same manner as the veins. They decrease in number, but increase in size, though the lymphatics are not so large as the corresponding veins.

The wall of the smallest lymph radicle is epithelial tissue only, but as they go on they take two other coats, very like those of the veins. The coats are so thin they are transparent. At very short intervals, the walls of the lymphatics are constricted by valves, formed by folds in the lining. (Fig. 247.)

FIG. 247.—Lymph vessel laid open length wise, showing arrangement of valves. (Gerrish.)

FIG. 248.—A lymph node with its afferent and efferent vessels. (Testut.)

Besides the tubes the lymphatic system includes *nodes* or glands. These are masses of lymphadenoid tissue in whose meshes are many white corpuscles. They sometimes have a fibrous capsule, and are easily identified. Sometimes they have no capsule, but are only infiltrated masses. (Fig. 248.) These nodes are plentiful in the neck, axilla, groin and abdomen.

THE GENERAL CIRCULATION OF THE BLOOD.

In an endless chain, it is difficult to select a place for breaking in. In the circulation of the blood through a system of closed tubes,

one must start somewhere, though there is no beginning to be found. By reference to Fig. 249 and following the arrows as the description proceeds, a clear idea of the general circulation may be obtained.

Starting with the left ventricle, the contraction of the heart throws blood into the aorta. The aorta sends off branches (systemic arteries) which divide and subdivide like the branchings of a tree, until the arterioles are reached, and then the capillaries in the body tissues (systemic capillaries).

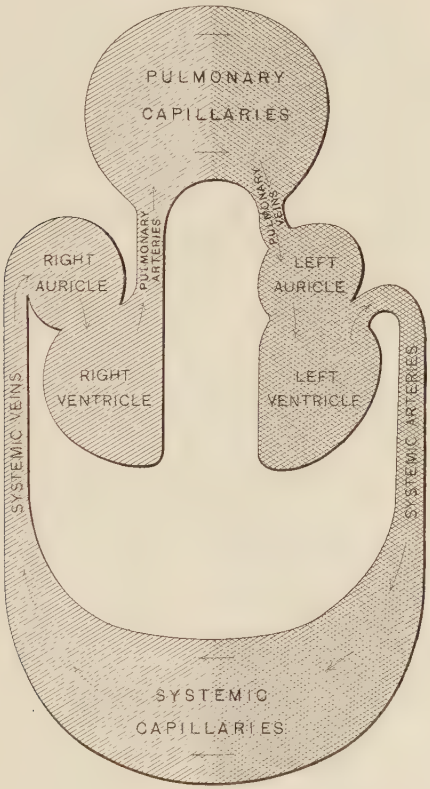


FIG. 249.—Diagram to show the course of the blood in passing from a given point through the two sets of capillaries to the starting-point. (Gerrish.)

Then the capillaries become venous radicles, they in turn collecting into larger veins (systemic veins), until finally the stream passes into the right auricle.

From the right auricle it goes into the right ventricle, and the contraction of the heart sends the blood into the pulmonary artery which divides and subdivides like the branchings of a tree, until the pulmonary capillaries are reached. These capillaries are in the lung

structure and then the capillaries lead into veins, which unite into the pulmonary veins which pass the blood into the left auricle, from which it flows into the left ventricle, to start the journey again.

There are four circulatory systems: (1) The *general,* or *systemic,* consisting of arteries, veins and their connecting capillaries, by which the arterial blood with oxygen and nutritive food products in it is carried to all parts of the body, with the return to the heart, *via* the veins of this blood, plus CO_2 and the nitrogenous waste from the cells in general.

2. The *pulmonary circulation,* in which the blood containing CO_2 and waste materials from the systemic circulation is sent by the pulmonary artery to the lungs. Here the CO_2 is removed, and a new supply of O is taken on, after which the blood returns to the left side of the heart by the pulmonary vein.

3. The *renal circulation* in which the blood goes from the left heart to the kidneys in which the nitrogenous wastes (urea) is removed. The purified blood then returns to the right side of the heart.

4. The *portal circulation* in which venous blood (part of which carries new food products) gathered from the stomach, pancreas, spleen and intestines are taken by the portal vein into the liver. (Fig. 292.) Here in the laboratory cells of the liver sugar is taken from the blood and stored in the liver cells as glycogen; nitrogenous waste materials from the work of the cells added to the products of intestinal putrefaction, such as skatol, indol, etc., are converted into urea, which goes back into the blood. This blood, united with that drained from the liver goes to the right side of the heart *via* the hepatic vein and inferior vena cava.

Each of these four systems thus contribute toward the regeneration of the circulating vital fluid. All the blood in the body must pass through these systems in turn.

If a vertical line is drawn through Fig. 249, the right half colored blue and the left half colored red, it would show that the right heart deals with unaërated blood only, while the left heart deals with aërated blood only.

THE GENERAL ARRANGEMENT OF THE ARTERIES.

It is evident that the bloodvessels are everywhere in the body since the smallest gash cannot be made through the skin without drawing blood. So wonderfully is the network of arteries arranged, if the direct blood supply of a part is cut off, there are other ways, through anastomosis by which the part may be supplied.

Divisions of the Pulmonary Artery.—The pulmonary artery leaving the right ventricle divides into right and left pulmonary arteries, and breaks up in the lung substance, like the branchings of a tree,

until the capillaries are reached. The exchange of O and CO_2 occurs, and the formation of little veins begins, which join others, until there are four pulmonary veins that empty into the left auricle.

Divisions of the Aorta.—The aorta is the largest artery in the body. It leaves the left ventricle and forms an arch toward the back and left.

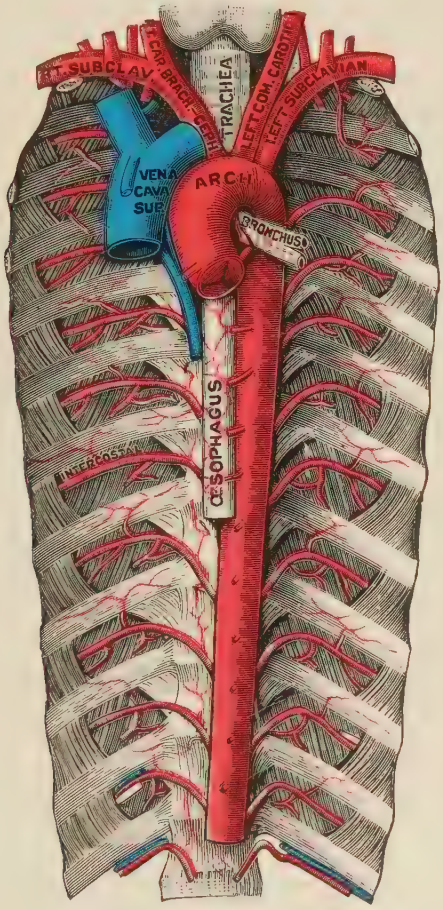


FIG. 250.—Thoracic aorta. (Testut.)

The first branches are two *coronary arteries* which provide nutrition for the heart itself. The large arteries that come off next supply the head, upper extremity and the walls of the chest. First, the innominate or brachio-cephalic arises on the right side, and immediately divides into the *right common carotid* and the *right subclavian.* Next, the left common carotid and the left subclavian arise from the arch (Fig. 239). The aorta now turns downward, and oppo-

site the lower border of the fifth thoracic vertebra it becomes the thoracic aorta (Fig. 250).

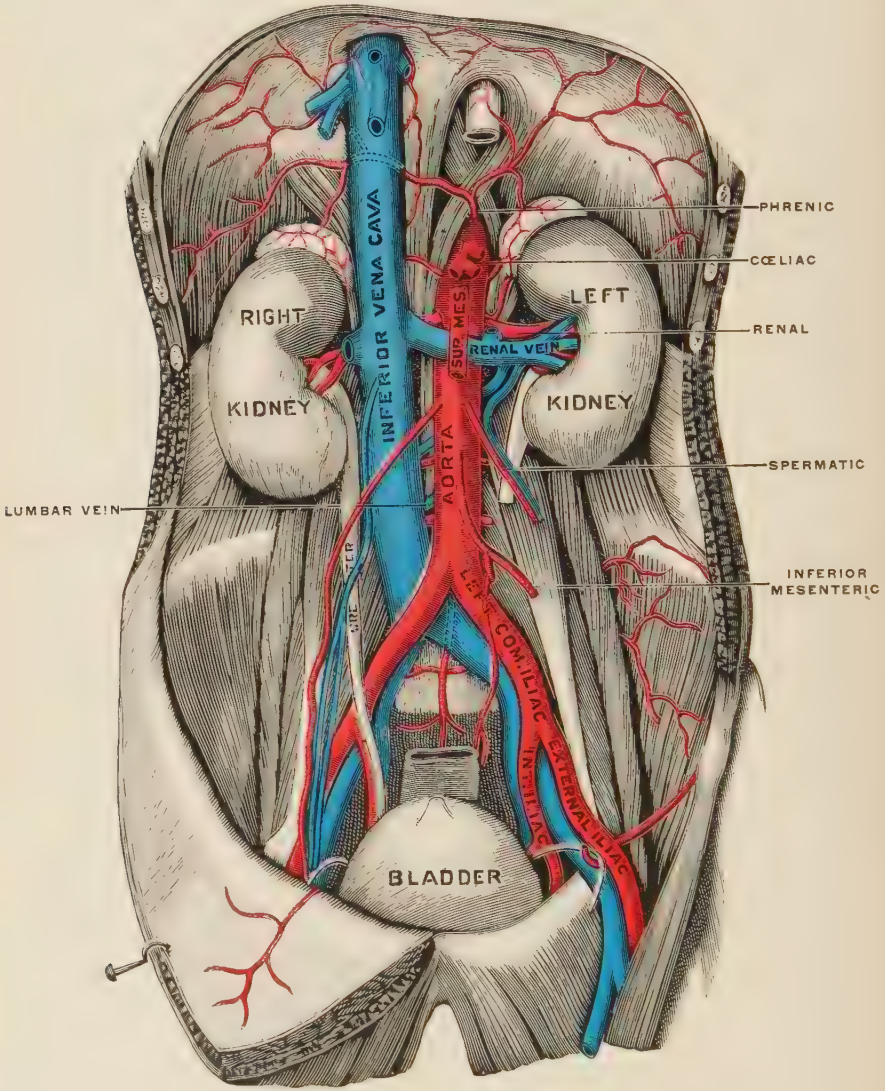


FIG. 251.—Abdominal aorta. (Testut.)

Continuing through the thorax it sends branches that supply the structures within the thorax and its walls. Reaching the diaphragm it passes through it and becomes the *abdominal aorta*. (Fig. 251.)

Many large branches are given off which supply the viscera within the abdominal cavity, the diaphragm and the walls.

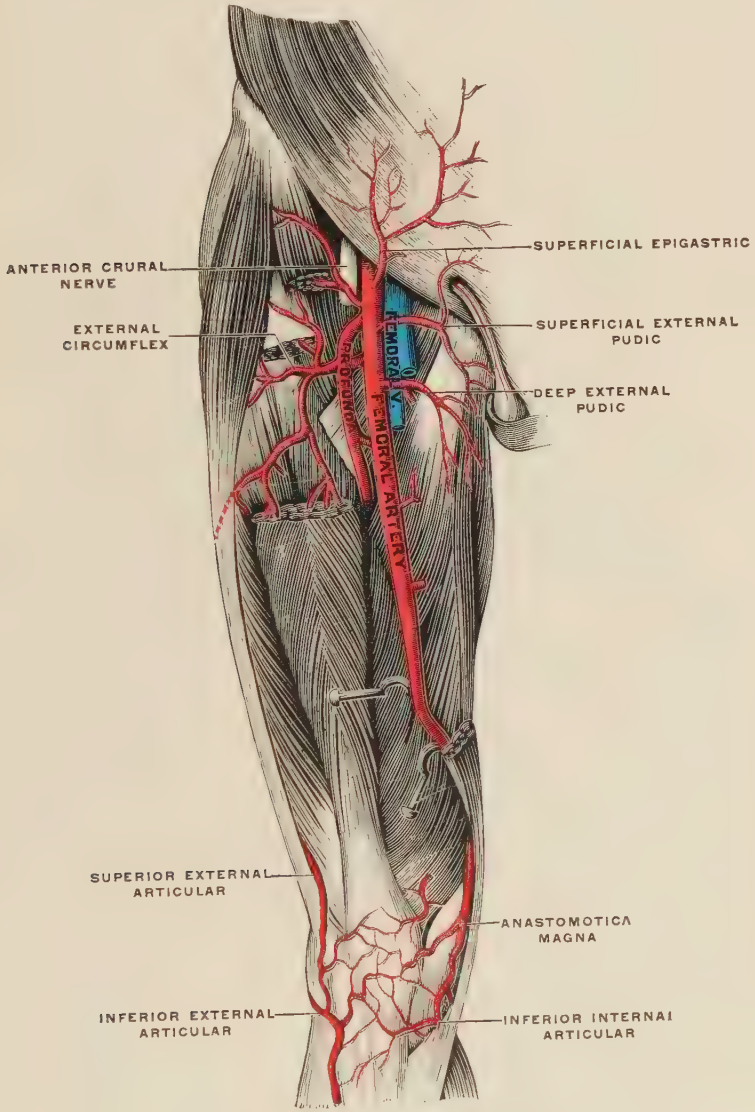


FIG. 252.—Femoral artery. (Testut.)

At the level of the fourth lumbar vertebra, the abdominal aorta divides into the *right* and *left common iliac arteries*. A little further, at the level of the articulation of the last lumbar with the first sacral

vertebra, the common iliac divides into the *internal* and *external iliacs.*

The internal iliac artery on each side goes into the pelvis and supplies the pelvic viscera and walls, the external genitals, the structures about the hip-joint and the inner part of the thigh. The external iliac artery goes out of the abdominal cavity into the thigh, and become the *femoral artery.* (Fig. 252.) The *femoral* artery has many branches as it passes through the thigh. Direct and recurrent articular arteries supply the hip-joint region. Deep

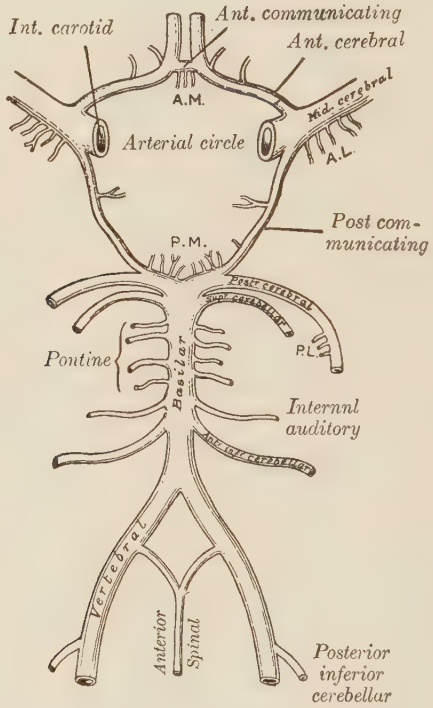


FIG. 253.—Diagram of the arterial circulation at the base of the brain. *A.L.*, antero-lateral; *A.M.*, antero-media; *P.L.*, postero-lateral; *P.M.*, postero-medial ganglionic branches. (Gray.)

branches go to the deeper muscles and the bone, while superficial branches supply the skin and superficial muscles. Anastomosing branches make connections between the other arteries, and, finally, the artery goes inward toward the back of the thigh, and two-thirds of the way down it becomes the *popliteal.*

The *popliteal* artery passes through the popliteal space, sending branches to the knee-joint, the hamstring and calf muscles. At the lower edge of the popliteus muscle it divides into the *anterior* and *posterior tibial* arteries.

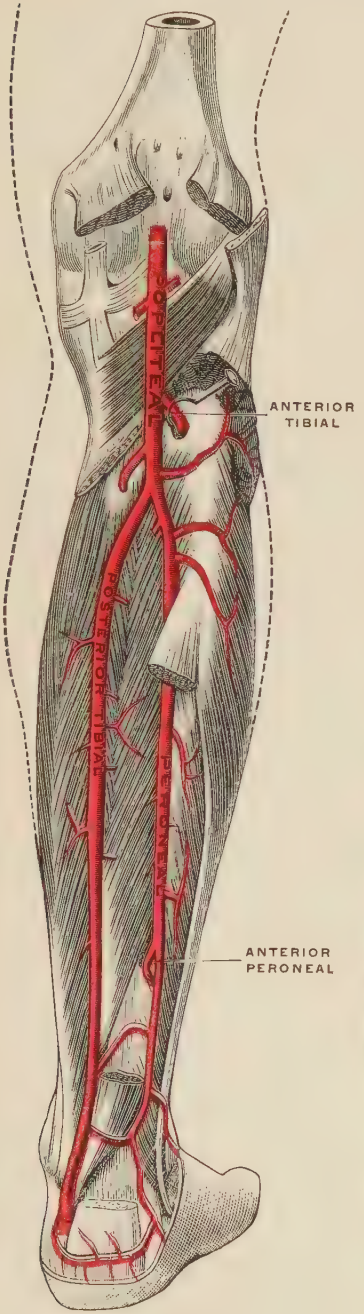


FIG. 254.—Arteries in the dorsal part of the leg. (Testut.)

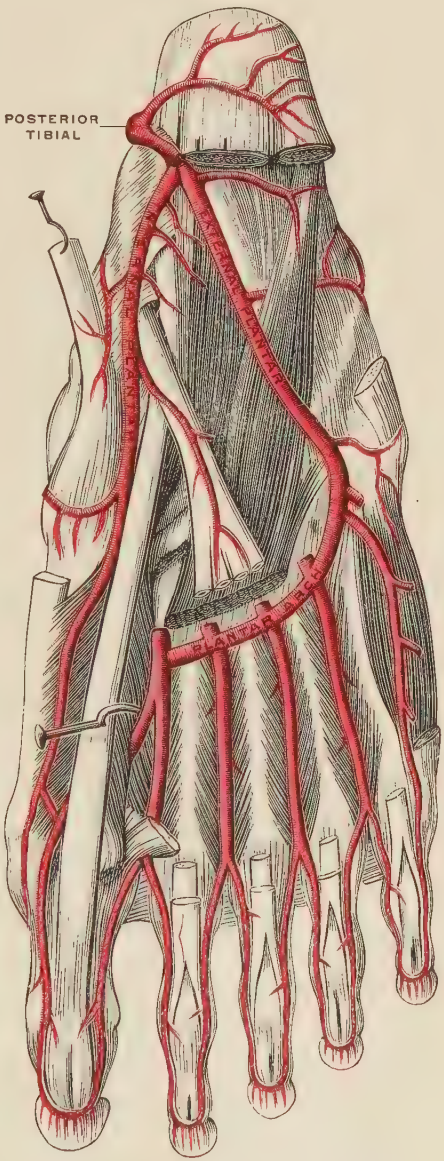


FIG. 255.—Arteries in the sole of the foot. (Testut.)

The *anterior* tibial, after giving off branches to the knee and ankle-joints and to the muscles on the front of the leg, continues as the *dorsalis pedis* on the back of the foot.

The *posterior tibial* sends branches to the muscles on the back and outer side of the leg, to the ankle-joint and heel and then divides into the medial and lateral plantar arteries.

Branches from the dorsalis pedis and lateral plantar arteries form the deep plantar arch, from which proceed the branches supplying the muscles, skin and fascia of the sole and toes. (Figs. 254 and 255.)

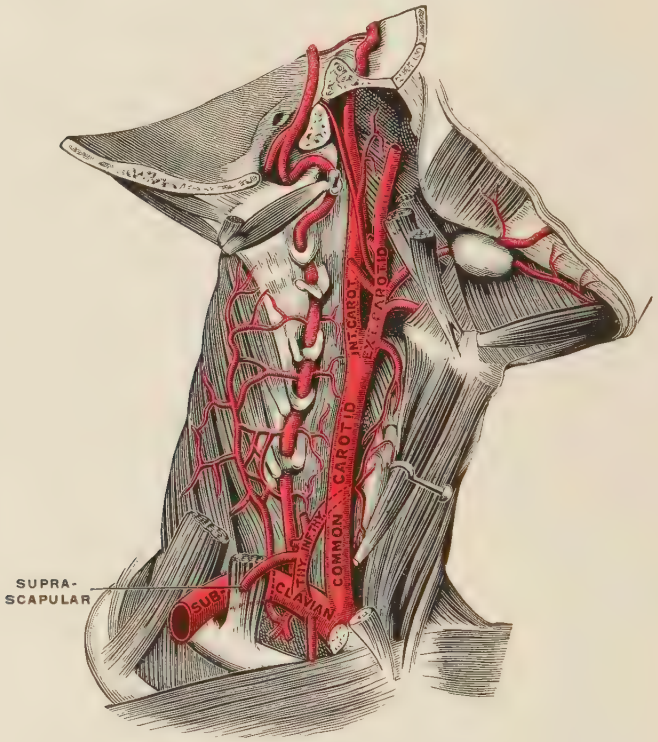


FIG. 256.—Right subclavian and carotid arteries. The vertebral artery is seen threading the costotransverse processes of the vertebræ. (Testut.)

Carotid Arteries.—Going back to the branches first given off, the common carotids divide into the *internal* and *external carotids*, as they pass up the side of the neck. (Fig. 256.)

The external carotid sends off various branches which supply the front of the neck, the face, scalp, pharynx and the external and middle ear. (Fig. 257.)

The internal carotid passes into the cranial cavity, sending off many branches, finally breaking up in the fissure of Sylvius. At

the base of the brain its branches anastomose with those of the *basilar* artery, forming the "circle of Willis."

From this circle the *anterior, middle* and *posterior cerebral* arteries pass off. Branches go to all parts of the brain and to the eyes. (Fig. 253.)

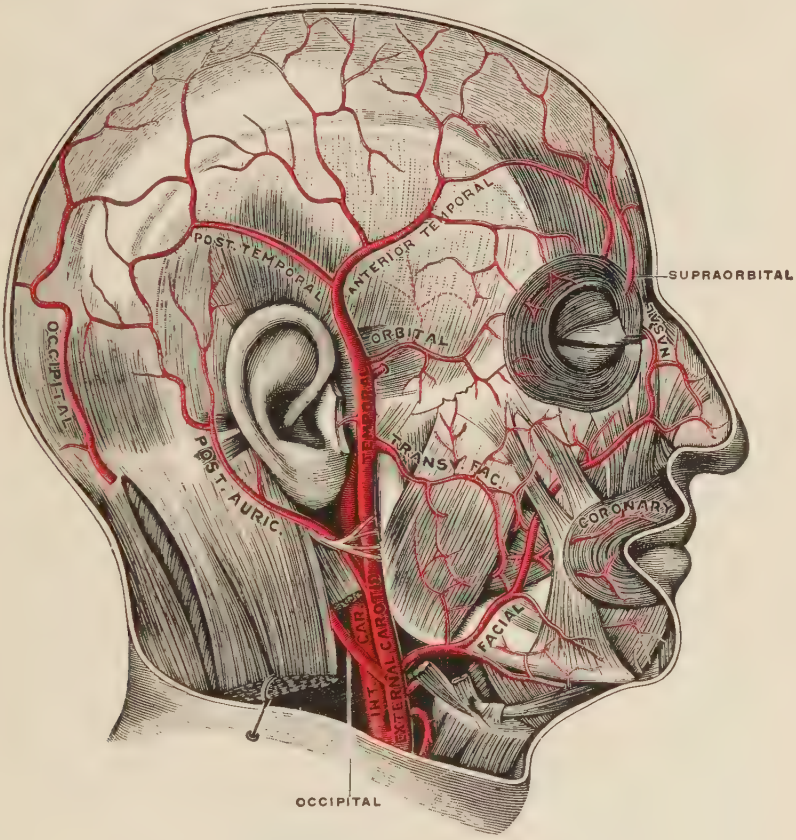


FIG. 257.—Superficial arteries of the head. (Testut.)

Subclavian Artery.—Soon after starting, the subclavian artery sends off a branch, the *vertebral.* The two *vertebrals* unite, forming the *basilar artery* at the base of the brain. The basilar goes to the interior of the brain and anastomoses with the branches of the internal carotid. (Fig. 256.) Other branches of the vertebral are the *internal mammary,* the *thyroid axis* and the *superior intercostal.*

The Axillary Artery.—The subclavius passes toward the outer side of the shoulder and opposite the lower border of the first rib becomes the *axillary.* The branches given off from the axillary go to the structures about the shoulder-joint. (Fig. 258.)

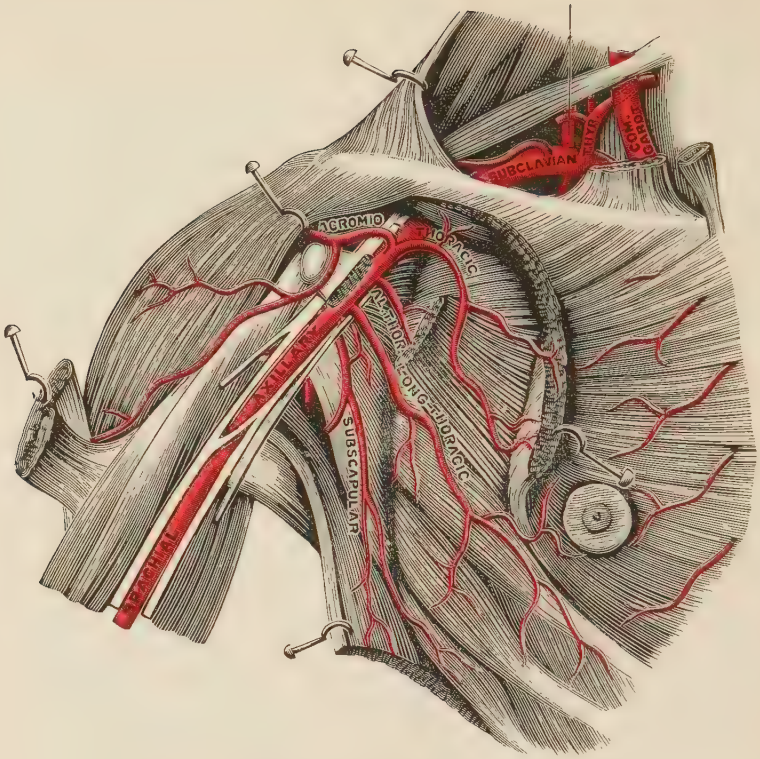


FIG. 258.—Axillary and subclavian arteries. (Testut.)

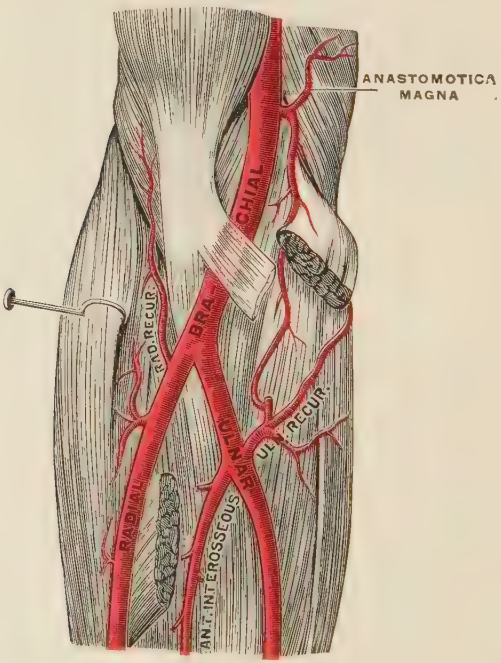


FIG. 259.—Arteries in the region of the bend of the elbow. (Testut.)

At the lower margin of the *teres major muscle,* the artery enters the arm and becomes the *brachial.* Branches from it supply the muscles, the humerus, the shoulder- and elbow-joints and the skin

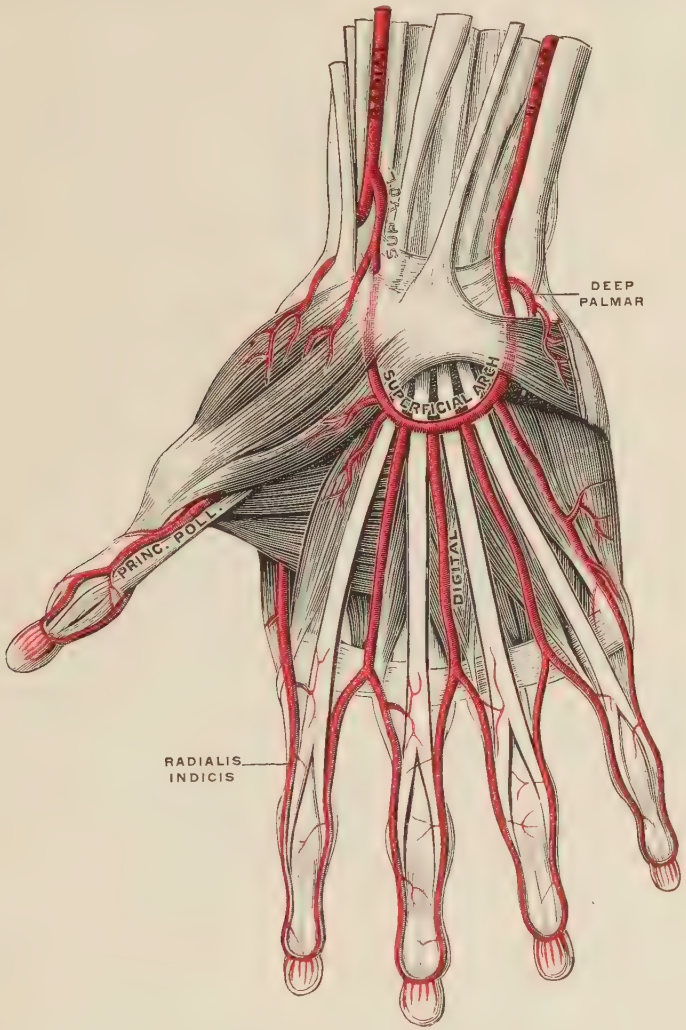


FIG. 260.—Superficial palmar arch and its branches. Of the digitals, only the third is labeled. (Testut.)

over the arm. Just below the elbow the *brachial* divides into the *radial* and *ulnar arteries.* (Fig. 259.) These pass down the forearm, sending branches to all contiguous parts, and finally meet in the two palmar arches, in the palm of the hand. (Fig. 260.)

The Thoracic Aorta.—The branches given off from the aorta while in the thorax are, the pericardial, the bronchial to the lung, the esophageal, the intercostals and the subcostal.

The Abdominal Aorta.—The abdominal aorta sends off a number of branches. Just below the diaphragm is a short trunk, the *cœliac axis*, from which the *gastric* artery for the stomach, the *hepatic* artery for the liver, and the *splenic* artery for the spleen pass off.

These three main arteries branch and send off anastomosing vessels which supply the viscera in the upper abdomen.

The *suprarenal* artery supplies the suprarenal glands.

The *superior mesenteric* supplies the upper intestine, with the lower intestine supplied by the *inferior mesenteric.*

The *renal* artery supplies the kidneys.

The *ovarian* artery supplies the ovaries.

The *phrenic* artery supplies the diaphragm.

The *lumbar* arteries go to the deep muscles of the back.

THE GENERAL ARRANGEMENT OF THE VEINS.

The veins return the blood from the peripheral parts to the heart. They are in two sets, the superficial and the deep, with frequent communicating veins between the two sets.

Systemic Veins.—The deep veins usually accompany the artery and the same name is given to both, as the hepatic artery, *hepatic vein.* There are no carotid veins, but the *internal jugular* drains the area supplied by the internal carotid and basilar arteries. It joins the subclavian vein to form the *brachiocephalic* or *innominate* on each side. The external jugular drains the external carotid artery area, emptying into the subclavian. (Fig. 261.)

The *azygos veins* form an anastomosis between the superior and inferior vena cavæ. They receive the venous blood from the back and sides of the thoracic walls.

The venous blood enters the right auricle by either the superior or inferior vena cava or by the coronary sinus. The latter comes from the substance of the heart.

The superior vena cava returns the blood collected from the head, neck, upper extremities and thoracic walls. The inferior vena cava from the lower extremities, the pelvis and the abdomen.

The Portal Vein.—A peculiar arrangement of the circulation is the portal system. The veins from the stomach, intestine, spleen and pancreas unite to form the portal vein. This enters the liver, and breaks up into capillaries, and when the venous radicles are formed, they unite with those resulting from the *hepatic artery,* and pass out of the liver as the *hepatic vein,* going to the inferior vena cava. (See Fig. 292.)

Superficial Veins of the Upper Extremity.—The superficial or subcutaneous veins lie between the layers of superficial fascia, and are visible under the skin. They occupy the areolar tissue network which holds the skin to the underlying structures.

In the upper extremity the superficial veins form a network on the back of the hand, and a smaller network on the front of the

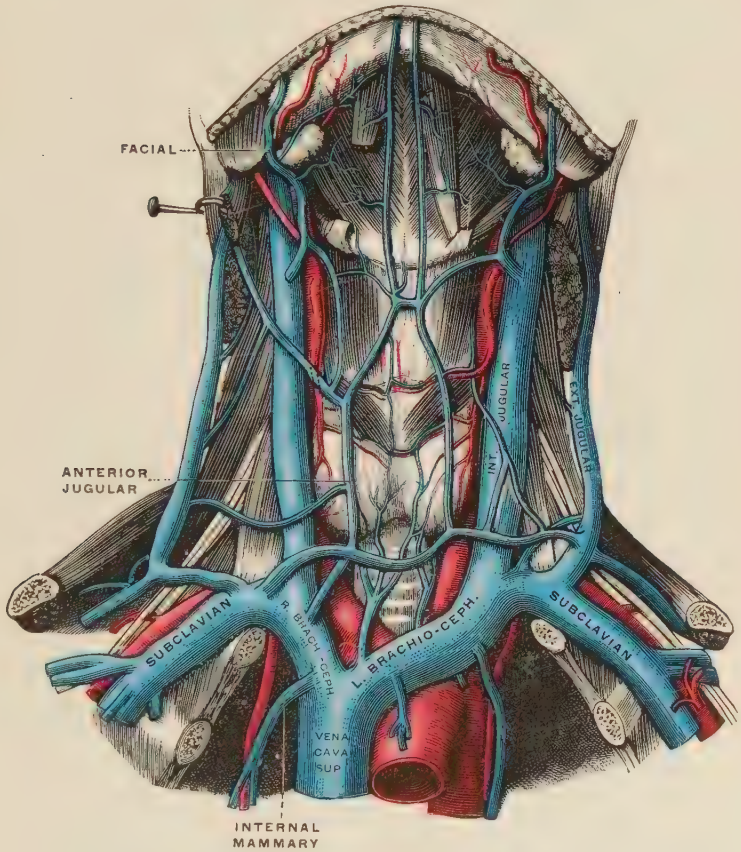


FIG. 261.—Veins of the neck and upper part of thorax, front view. (Testut.)

wrist. Those on the back of the hand unite to form the *radial* vein which runs up the outer side of the forearm to just above the elbow where it joins the *median cephalic* to form the *cephalic*.

The *posterior ulnar* vein begins on the inner side of the network on the back of the hand, passes up to the elbow and there receives the *anterior ulnar*. This latter comes from the wrist along the inner side of the front of the forearm. These two ulnar veins form the

common ulnar vein which joins the *median basilic* to form the *basilic*. The *median* vein starts from the plexus on the front of the wrist,

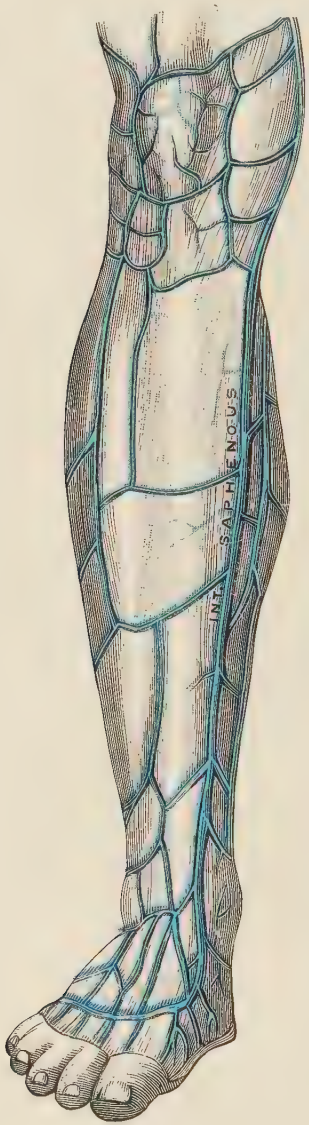


Fig. 262.—Superficial veins of the front of the leg and foot. (Testut.)

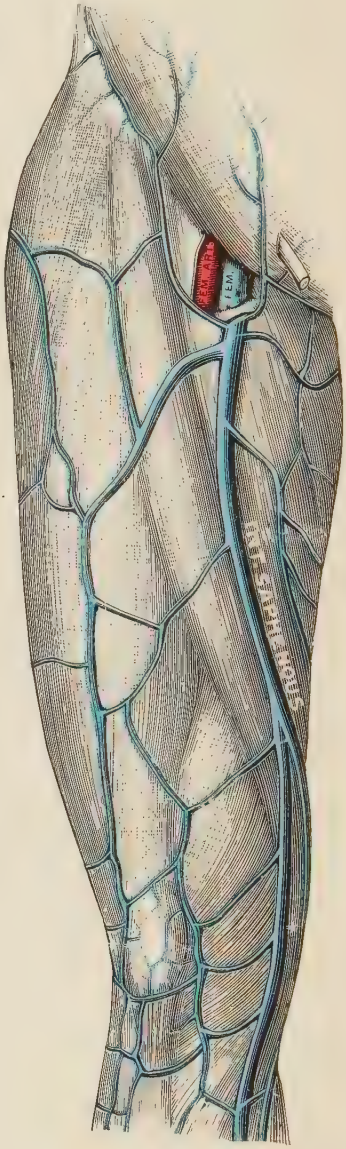


Fig. 263.—Superficial veins of the front of the right thigh. (Testut.)

goes to just below the elbow where it is joined by the *deep median* vein, and then divides into the *median cephalic* and the *median basilic*.

The *cephalic* runs up the outer side of the front of the arm, to the axillary, into which the basilic also empties.

Superficial Veins of the Lower Extremity.—These veins have numerous valves to prevent the force of gravity interfering with the onward progress of the blood toward the heart. There are two main venous trunks, internal and external, which begin in a network over the instep and on the dorsum of the foot, called the dorsal plexus. This was formed by the veins from the toes, the inner and outer borders of the foot.

Long Saphenous Vein.—The *internal* or *long saphenous* vein begins at the inner part of the dorsal plexus (Fig. 262), passes up the inner side of the thigh nearly to Poupart's ligament, and there enters the femoral vein. It passes in front of the internal malleolus, and back of the internal condyle of the femur, and is joined by many superficial veins and numerous branches from the deep veins of the sole, leg and thigh. It contains from seven to twenty valves. (Fig. 263.)

Short Saphenous Vein.—The *external* or *short saphenous* vein begins at the outer part of the dorsal plexus, passes behind the external malleolus, and then on the outer and back part of the leg to the lower part of the popliteal space, where it joins the popliteal vein. It is joined by superficial veins from the foot, heel and back of the leg. It communicates with the internal saphenous, and has from nine to fourteen valves. (Fig. 264.)

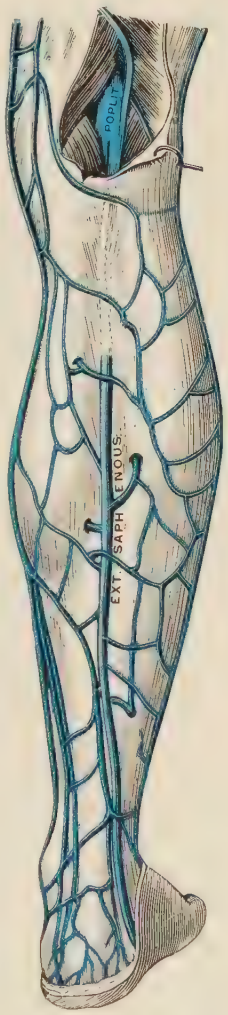


FIG. 264.—Superficial veins of the dorsum of the leg. (Testut.)

THE GENERAL ARRANGEMENT OF THE LYMPHATICS AND THE NODES.

The lymphatic ducts are similar to small veins in that they are very small at the beginning, until by uniting with others, large trunks are formed. The ducts in the right upper half of the body, the right side of the head, the heart, neck, chest, upper extremity and the upper surface of the liver, are all drained into the *right lymphatic* duct, which enters the right subclavian vein at its junction with the right internal jugular.

All other parts of the body drain into the *thoracic duct.*

The Thoracic Duct.—This begins in the abdomen just in front of the spine, on a level with the second lumbar vertebra.

An expanded pouch, the *receptaculum chyli*, receives the contributions from the surrounding digestive organs, and then the duct passes upward to the level of the fourth thoracic vertebra (a distance of from 15 to 18 inches), and there enters the left subclavian vein at its juncture with the left internal jugular. (Fig. 265.)

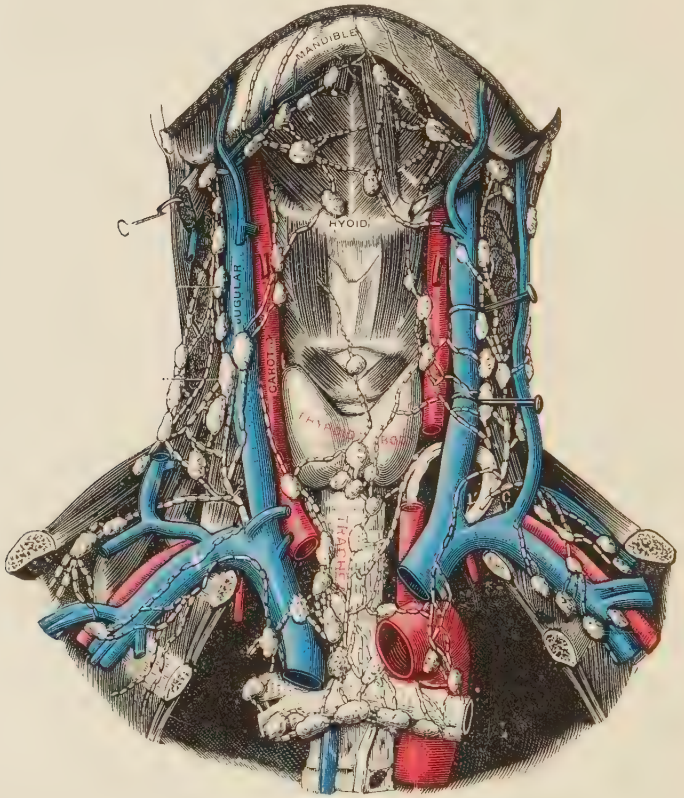


FIG. 265.—The lymph nodes of the neck and upper part of the thorax. (Testut.)

The diameter of the duct is about that of a goose quill. Double valves guard the openings of both the right lymphatic and the thoracic ducts to prevent any regurgitation of lymph. Collections of nodes are found in the neck, axilla, groin and abdomen, wherever deleterious substances are most apt to need fighting by the lymph corpuscles, *i. e.*, the white corpuscles or phagocytes. (Figs. 265, 266, 267.)

Fig. 266.—The nodes and vessels of the upper limb. (Testut.)

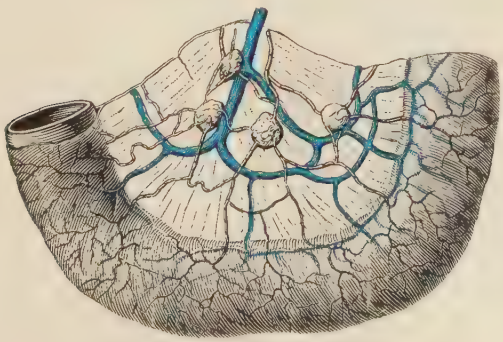


Fig. 267.—Mesenteric nodes. (Testut.)

THE PHYSIOLOGY OF THE CIRCULATION.

The blood is the fluid that is carried to all parts of the body and which carries in itself the nutrient material needed by every cell, the waste products from the working cells and the secretions of the ductless glands.

The heart sends out about 4 ounces of blood at every contraction, or every .86 second, or an average of 72 times a minute. This is the rate for the majority of persons, but individuals may have a more or less rapid rate within the limits of perfect health. Young children have a more rapid pulse, and the aged are apt to have it slower. During exercise and digestion the rate is increased.

Systole and Diastole.—Blood is sent from the heart by the contraction of the cardiac muscle, rhythmically, with periods of rest. The contractions constitute *systole*, the rest periods, are *diastole*.

The Cardiac Cycle.—The contraction may be likened to a circular wave that starts in the upper part of the heart, in the auricles, at the entrance of the large veins, and passes downward to the lower part of the ventricles. After the auricles become filled with blood from the vena cavæ and the pulmonary veins, their systole begins, forcing the blood into the ventricles, through the auriculo-ventricular openings. This occupies about .16 second, after which their diastole occurs, until it is time for the next contraction.

Immediately following the auricular is the ventricular systole in which the blood is thrown into the aorta and pulmonary artery. This lasts .30 second, after which the ventricular diastole lasting .40 second occurs.

At the beginning of the auricular systole, the valves between the auricles and ventricles are open, while those between the ventricles and large arteries are closed. At the beginning of the ventricular systole, the mitral and tricuspid valves close, the aortic and pulmonary open. The diastole of the auricles begins thirty seconds earlier than that of the ventricles, thus allowing time for the blood from the large veins to flow into and fill the auricles, while the ventricles are still in systole.

With the ventricles in systole the auriculo-ventricular valves (mitral and tricuspid) are necessarily closed to prevent the regurgitation of blood from the ventricles into the auricles. The diastole or relaxation of the ventricles allows the weight of the contained blood in the auricles to open the auriculo-ventricular valves, and the blood to flow into the ventricles. With the auricular systole there is a complete emptying of blood from auricles to ventricles.

At the beginning of the ventricular diastole the recoil of the aorta and the pulmonary artery sends some blood backward toward the heart. Before it can enter the heart it runs in behind the semilunar valves and closes them, so that during this rest period the

auriculo-ventricular valves are open and the semilunar valves (pulmonary and aortic) are closed.

The greater the amount of blood received by the ventricles, the stronger is their contraction, and the less frequent. Quickened heart action usually means a smaller output each time.

This alternation of systole and diastole is the *cardiac cycle.*

Apex Beat.—The rhythmic contraction of the heart may be felt by placing the hand about its own width from the center line of the chest, at the level of the fifth interspace, or if the breasts are not pendulous, about ½ inch below the nipple, on the left side. The heart swings forward and slaps against the chest wall, so the impulse can be felt, and sometimes seen.

The Pulse.—Other places where the effect of the heart's systole can be observed are where a fair-sized artery comes near the surface. At the side of the neck, at the radial side of the front of the wrist, etc., this impulse, called the *pulse* may be felt. In the neck it is synchronous with the apex beat, but it is a little later at the wrist, and still later in the arteries farther off.

It will be noted that the pulse does not present quite the intermittent character of the apex beat, but is remittent. That is, there is a continuous flow of blood, but rhythmic waves of greater force are present.

Venous Pulse.—This is developed in the internal jugular vein. On account of the firm or bony walls of the cranial veins being pressed upon to take up the force of the arterial blood, the pulse wave is transmitted, as through rigid tubes, into the jugular veins.

Steadying the Output of the Heart.—The blood leaves the heart in spurts, going into the aorta and pulmonary artery, but in the smallest arteries and capillaries, the flow is steady without any waves. This change is due to "arterial recoil" and "widening the bed."

Arterial Recoil.—The aorta contains much elastic tissue, so that it is easily distended as the blood is thrown into it at each ventricular systole. When this impulse is over, the walls recoil, pressing down upon the blood, and imparting a steady push to it. As the aortic valve is closed, the blood cannot go back to the heart, and must go toward the periphery.

The larger arteries contain a greater amount of elastic tissue than the small ones do, so this pressure of the walls continues for some distance from the heart, making the flow more steady. This pressure upon the blood in the arteries is called *arterial tension,* and it is subject to various influences which increase or decrease it.

The wave induced by the heart's systole is lost in the small arteries, and in the capillaries, so the flow is steady and slow. As the blood goes out into the "arterial tree," there is more resistance to its onward flow, due to the narrowing of the tube. This is "peri-

pheral resistance," which is increased or lessened by muscular contraction or relaxation. The greater the resistance, the harder the heart has to pump to send the blood to its destination, with consequent increase in arterial tension. Arterial tension or *blood-pressure* represents the pressure against the sides of the bloodvessels exerted by the moving blood. This pressure distends the walls of the bloodvessels, so that any cut across an artery is followed by a vigorous spurt of blood.

The amount of pressure varies in different parts of the cardiac cycle, highest during systole, lowest during diastole.

The systolic pressure represents the *force* of the heart-beat mainly, while the diastolic represents the load sustained by the walls of the arteries. If there was no arterial recoil the diastolic pressure would be about zero.

If peripheral resistance is increased, and the rate of the heart is diminished, the diastolic pressure is high. With the diastolic pressure low and the heart-rate increased, peripheral resistance is probably less.

The higher and more persistently high the diastolic pressure is, the greater the strain on the heart and arteries.

Average systolic pressures are 150 mm. Hg., with diastolic pressure of 80 to 90.

Some other factors that increase tension or blood-pressure are standing, walking or running, as compared with sitting or lying; mental strain and very hearty meals. Cold baths increase while full tepid baths decrease the pressure. Strong emotions increase the pressure.

The pressure during systole is lowest in children, gradually increasing as the years advance until it becomes relatively high in the aged. Whether this is due to a gradual hardening of the artery walls is open to discussion, as the less elastic these walls are the greater is the rise in systolic pressure with every heart beat. But, as high blood-pressure occurs in early middle life in some cases, there are evidently many causes still unknown. The secretion of some of the ductless glands is a potent influence, one way or another. The pressure in the veins is usually zero or even negative, as the force of the heart's contraction is lost in the capillaries.

The Suction Pump.—So little force has the blood in the capillaries, or in the neighborhood of the ultimate tissue cell it would simply stay there indefinitely, unless some force could carry it along. The force pump has lost its effect, but a suction pump is now developed which returns the venous blood to the heart. It is developed by the respiratory movements, the changing size of the heart, muscular contractions and joint movements. During inspiration, the diameters of the chest increase, producing a potential vacuum. This sucks the air into the lungs from outside, and sucks the blood into

the chest and heart from other parts of the body. The blood so drawn in must be venous, as the strong action of the heart sends the arterial blood in the opposite direction. The inspiratory movement also draws the lymph from the periphery, as the lymph vessels are connected with the venous system.

A considerable amount of suction is exerted by the relaxation of the heart, drawing the blood from the vena cavæ and pulmonary veins into the auricles. (See page 313.)

There are many opportunities for the development of vacuums in the veins, as the blood is in this system of closed tubes. If a vein is pressed upon, the walls collapse, the blood is forced from under the pressure, and when the pressure is removed, a vacuum results. The blood that was pressed out has had but one direction in which it could go forward, as the valves prevent its backward movement. The blood must rush forward to fill the vacuum, so the net result of the pressure on the vein is to carry the venous blood toward the heart. Every muscular contraction, with the broadening of the muscle produces pressure on the vessels contained in its substance, with suction. A part of the body in which the muscles are not used becomes, as it were, "water-logged," with nothing to start the venous blood and lymph toward the heart. By reason of the attachment of the deep fascia to the large veins at the joints, movement of the latter pulls upon the veins, and increases suction.

By these means, the force pump on the arteries, and the suction pumps on the veins and lymphatics, the blood gets around the body, making a complete circuit every twenty-two seconds.

Quantity of Blood in Body.—The quantity of blood is about 9 per cent of the body weight. This approximates 13 pints in an average man. It is not enough to furnish every part with a full supply all the time. If the muscles and skin have plenty, there is not sufficient for the digestion of a hearty meal, or to allow much effective brain work.

Approximately one-fourth of the blood is distributed to the liver, to the skeletal muscles, to the heart and large bloodvessels, while the rest of the body has the last quarter.

Fortunately, the glandular organs have alternating periods of work and rest. When they work, they require a large supply of blood, which goes to them through the vasomotor nerves acting in harmony with the secretory nerves of the sympathetic. These organs are usually supplied by the lesser-sized arteries that have considerable muscle tissue in their walls. Their caliber is readily decreased by the *vasoconstrictors* or increased by the *vasodilators*, thus lessening or increasing the blood supply. When the muscles are in vigorous contraction, much blood is needed by them and by the skin, and their demand is more insistent than that of even the digestive organs. The process of digestion may be suspended by hard muscular work soon after eating.

The Vasomotor Nerves.—These nerves which regulate the size of the smaller arteries are derived from the cells in the lateral horns of the gray matter of the spinal cord from the second thoracic to the third lumbar segments. The fibers come out of the cord in company with the anterior motor roots of the spinal nerves, receive a medullary coat and sheath and are the white rami communicantes or preganglionic fibers of the autonomic nerves. They pass into the vertebral ganglia and arborize around their cells. From the cells gray fibers pass out, which join spinal nerve trunks, going in them to the walls of the bloodvessels in the skin, head, face, neck, the trunk, the upper and lower extremities and the abdominal viscera.

The distribution is to the circular fibers which are either stimulated to contract and so lessen the amount of blood going through—or their contraction is inhibited, so more blood passes through the artery.

These muscles in the bloodvessel walls maintain a certain "tonus" in health. Some surmise this is due to the influence of the vagus.

The general vasomotor center seems to be in the medulla, though the cells in the cord at different levels may also possess regulatory power.

This alternation of full blood supply to the different parts keeps the blood on the move and improves its quality.

The Nerve Supply to the Heart.—The cardiac muscle has a method of contraction that differs from that of voluntary or involuntary muscles.

It has a rhythmic action that is maintained after the nerve supply through the general nervous system is cut off. The contraction runs through the heart from base to apex in a wave, synchronous on both sides.

It has been thought that the rhythmic contraction is due to intrinsic sympathetic ganglion cells which send motor impulses through their axones to the muscle cells. Some parts of the heart, as the upper portion, have many of these cells and contract very strongly. The apex has few and its contraction is weak.

Another theory is that the contractions originate in the muscle cells by reason of the chemical stimulation by the surrounding fluid.

The heart of an animal can be removed from the body, and, by placing it in a solution of certain salts, be made to continue its contraction for a long time. This, without any external stimulus.

This seems to imply a response to chemical stimuli of the muscle cells without regard to nerves.

The fact remains, however difficult it is to explain, that the heart muscle possesses some power of independent action within itself.

It receives stimuli of two kinds from the central nervous system accelerator and inhibitory, by which its rate, force, regularity of rhythm and responsiveness are affected. It is an autonomic tissue.

The *accelerator* nerve is supposed to come from the medulla, through the cord, the first thoracic and last cervical ganglia of the sympathetic, and finally the cardiac plexus.

Its *inhibitory* fibers coming from the inhibitory center, possibly in the medulla or floor of the fourth ventricle, pass out in the vagus and come into relation with the ganglionic cells in the heart muscle. Postganglionic fibers from these cells go to the heart muscle cells and inhibit their action or decrease their rate.

The balance maintained between the accelerator and inhibitory influences determine the rate of beat.

Various influences modify the action of these two groups of nerve fibers. From the psychic centers emotions may change the heart rhythm; muscular activity and the standing position increase it, while age, food, variation in blood-pressure, etc., will have their varying effects. Increase of thyroid secretion in the blood increases the heart-rate and blood-pressure. Febrile conditions are accompanied by increased rate.

The Work of the Lymph.—The lymph vessels contain lymph, a colorless fluid which is the plasma of the blood after it has leaked through the walls of the capillaries into the spaces surrounding the tissue cells, plus the material coming from the cells. This material includes all kinds of secretions as well as waste. This fluid after the cells have taken what they need must go back into the blood-vessels. The venous capillaries cannot take it all up, so the open stomata of the lymph radicles must do it. Physiologists are not agreed as to just how this is done, but it is done, and the surplus lymph goes through the lymphatics to the venous system. During inaction, there is little flow, but when the venous suction pumps pull, the flow becomes active. The peristaltic action of the muscles of the intestine moves the lymph in that region.

The *lymph nodes* serve to strain out of the lymph certain deleterious substances. In them the white corpuscles, or at least, some of them, seem to originate.

The Work of the Red Corpuscles.—Some of the red corpuscles are formed in the red marrow of the bones, but it is open to question if that is the only source for their production.

Their chief constituent is hemoglobin, which gives the red color to the blood. It is a form of organic iron, which has a strong affinity for oxygen. In the lungs the hemoglobin takes oxygen from the air and carries it in the blood stream to the tissues. The cells take it and by a process of oxidation use it, producing some form of energy and carbon dioxide. The latter is carried by either the red corpuscles or plasma to the lungs to be eliminated.

The Work of the White Corpuscles.—This has been the subject of much investigation. All white corpuscles are not alike. The two main groups are leukocytes and lymphocytes. The leukocytes

wander about, but the lymphocytes seem unable to do so. It is probable the white corpuscles protect the body from pathogenic bacteria and other foreign organisms. The formation of substances in the blood which immunize the body to infection is thought to be the work of the white corpuscles.

They aid in the absorption of fats from the intestines and also of peptones. They may take some part in the coagulation of the blood, and help maintain the normal supply of proteins in the blood.

The Blood as a Carrier.—The plasma is involved in serving as a common carrier between the various parts of the body. Among the substances carried are oxygen, carbon dioxide, water, nitrogen, various proteins as fibrinogen, paraglobulin, and serum albumin. Substances called extractives, as fats, sugars, urea, uric acid, creatin, jecorin, glycuronic acid, lecithin, cholesterin and lactic acid are also present. The mineral salts, include combinations of chlorine, carbon, sulphur and phosphorus with sodium, potassium, magnesium and iron. And, yet more. Enzymes, the internal secretions, immune bodies, complements and opsonins, and, prothrombin and antithrombin. With such a complex organization, the plasma gives up different substances to different cells and receives a supply of other material to carry around, either to be used by other cells, expelled from the body as waste or used to stimulate the functions of other parts.

Coagulation of the Blood, or Clotting.—Unless there is some injury or disease of the bloodvessels, while the blood remains in them, it is fluid. If the vessels are cut, so the blood escapes, there is formed a solid plug or clot at the open ends, which sooner or later stops the bleeding.

This coagulation of the blood is produced by a network of *fibrin*, in which the corpuscles are caught. Fibrin does not exist in the blood while it is in the vessels, but develops from such substances as thrombin, fibrinogen, the platelets, possibly, the white corpuscles, when the blood escapes.

If these antecedents of fibrin are lacking in the blood coagulation does not take place, and bleeding may continue indefinitely after it begins. The condition is known as "hemophilia," and its subjects as "hemophiliacs" or "bleeders."

QUESTIONS.

Describe the heart, and make a diagram of it.

Compare the structure of an artery and a vein with reference to the work done by each.

What is the relation of capillaries to cells?

How do lymphatics begin?

Why should two sets of bloodvessels be needed to return blood to the heart, when one set is sufficient to carry it from the heart?

What is the pulmonary circulation?

What is the portal circulation?

Trace the course followed by a red corpuscle in going from the right auricle to the palm of the left hand.

Trace the course going from the left ventricle to the right kidney.

What parts of the body are drained by the inferior vena cava?

What area is drained by the long saphenous vein?

What area is drained by the portal vein? By the hepatic vein? By the internal jugular vein?

Describe the thoracic duct.

What is the "cardiac cycle?"

How is the intermittent flow of blood from the heart changed to the steady flow, with waves, in the arteries?

What work is done by the blood plasma?

What work is done by the red corpuscles?

What work is done by the white corpuscles?

What is "arterial tension?"

How does the blood get back to the heart from the capillaries?

CHAPTER X.

THE RESPIRATORY SYSTEM.

RESPIRATION may be defined as an exchange of gases, of which the object is to provide oxygen for the combustion in the tissues and to remove the products of combustion in the form of carbon dioxide.

As with other vital processes of the body, the essential action of respiration takes place in the microscopical tissues, and the entire mechanism is so arranged.

The process may be divided into two parts, *external respiration,* during which the air external to the body is carried to the lungs, and the exchange occurs between the blood in the capillaries of the pulmonary arteries and the air in the alveoli; and *internal respiration* which occurs in the ultimate tissues with the exchange between the blood in the systemic capillaries and the tissue cells.

THE ORGANS CONCERNED IN RESPIRATION.

The passages through which the air passes to the microscopical tissue cells, in their order, are:

The nose (mouth).
Posterior nares (naso-pharynx).
Pharynx.
Larynx.
Trachea.
Bronchi.
Bronchioles.
Alveoli.

The Nose.—The nose is a prominent feature of the face, and varies in shape according to the race and the climatic conditions under which the race has developed. Tropical races have rather flat noses, with short air passages, while races living in colder regions develop longer air passages with more prominence of the nose. The nasal bones are short and small, forming the "bridge of the nose," and to them is attached a cartilaginous addition that provides for movement of the nostrils and takes up the force of external blows to a considerable extent. Small muscles are attached to the nose providing for facial expression and extra efforts in breathing.

The nose is lined with mucous membrane containing many "goblet cells," and having a rich blood supply. This membrane does not cover the small surface only that is visible on cursory

inspection, but is continued over a large area by covering the "turbinated bodies." These are three in number, on each side, and their convoluted shape gives a large area of warm mucous membrane over which the air passes on entering the nose. The air can thus be warmed before it reaches the more delicate structures beyond.[1]

The Posterior Nares.—Through the posterior openings of the nose, the way leads into the naso-pharynx, on the wall of which is a mass of adenoid tissue. When this tissue becomes hypertrophied, the condition known as "adenoids" develops, with interference with the easy ingress of air, and consequent normal development of a child (Figs. 237 and 238).

The Pharynx.—The pharynx is the space at the back of the mouth, and is divided into the naso-pharynx above, the oro-pharynx, opposite the tongue and the laryngo-pharynx, just above the larynx. It is 5 inches long, and on the posterior wall are two openings which are the beginnings of the Eustachian tubes for carrying air to the middle ear.

On the outside of the pharynx are a number of muscles that constrict its caliber, forcing the bolus of food, after mastication, from the mouth into the esophagus.

It is lined with a continuation of the mucous membrane of the nose, mouth, middle ear and larynx, but ciliated epithelium to the level of the hard palate provides for the waving outward of mucus and its easy removal.

The Larynx.—Opening from below the pharynx, are two apertures, the esophagus and the larynx, and except during the act of swallowing, both are open at all times. When a bolus of food passes into the esophagus, a trap-door closes over the larynx to prevent food going into it. This door is the *epiglottis.* (Fig. 268.)

The Epiglottis.—The epiglottis is a thin triangular leaf-like piece of cartilage, attached to the base of the tongue and to the upper and anterior part of the larynx. Its action is involuntary, but when the coördination of the muscles of the pharynx and those attached to the epiglottis becomes impaired, it may fail to close over the larynx and food may enter the latter. This will cause choking, and violent efforts at coughing it out. If the material enters the trachea it may entirely block the ingress of air.

The appearance of the larynx is that of an irregular box made of four pieces of cartilage, and the muscles and ligaments that hold them together. The cartilage keeps the lumen open, and the muscles on the outside are concerned in swallowing, respiration and phonation.

Over this box-like structure, at the upper end pass two bands of fibrous tissue, covered with mucous membrane. These are the

[1] Under the description of the nerve of smell, additional details are given of the nose.

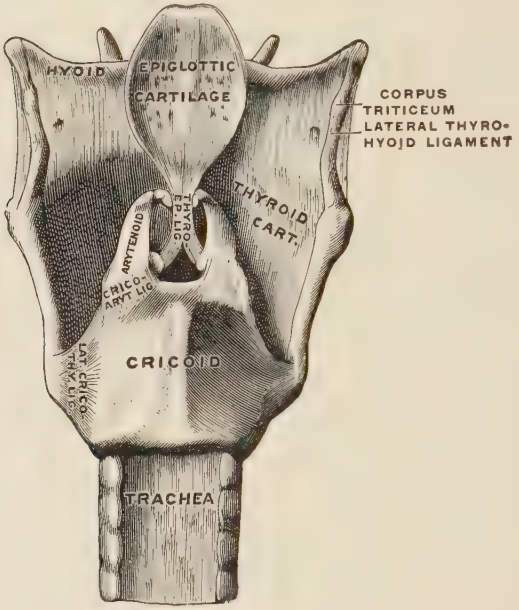


Fig. 268.—Laryngeal cartilages and ligaments from behind. (Testut.)

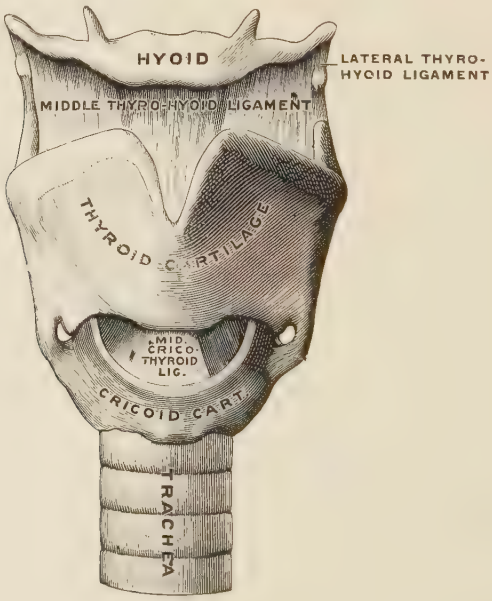


Fig. 269.—Laryngeal cartilages and ligaments from in front. (Testut.)

vocal cords. They are so placed as to leave a triangular opening which varies in width or which may be entirely closed. This opening is the *glottis.* The variation of size provides for the passage of more or less air, according to circumstances. The air coming from the lungs sets the vocal cords in vibration, causing sound.

The glottis may be closed at the end of inspiration to prevent the expiration of air and give fixation of the diaphragm in connection with the muscles of the abdominal wall to produce compression of the viscera below, as in defecation, micturition and vomiting. It may also be closed to fix the chest and give greater power in muscular efforts, such as lifting, jumping, etc. It is to be noted that by the voluntary closing of the glottis at the beginning of inspiration, the suction effects of the inspiratory movements can be increased.

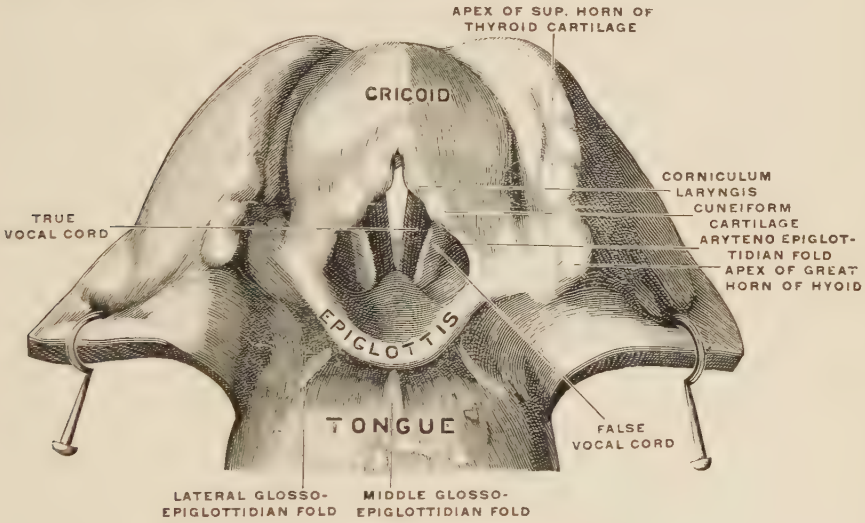


FIG. 270.—Larynx, viewed from above. (Testut.)

The Trachea. (Fig. 271.)—The trachea is the next part of the respiratory tract and consists of a tube about $4\frac{1}{2}$ inches long, made of fibrous tissue in which is imbedded incomplete cartilaginous rings whose function is to keep the tube patulous. The back of the trachea lies in contact with the esophagus, and on that surface the cartilaginous rings are lacking so as not to interfere with the passage of food.

The Bronchi.—The trachea divides into two branches that go to the right and to the left into the lungs, and are called the *primary bronchi.* These are large tubes with cartilaginous rings throughout their circumference, and are lined with a mucous membrane continuous with that of the larynx. The bronchi divide into smaller

tubes (bronchial tubes) which continue dividing and subdividing until the diameter becomes very minute. The cartilage in the walls continues until the tubes become as small as $\frac{1}{50}$-inch in diameter. These tiny tubes are the *bronchioles*, and they vary in diameter between $\frac{1}{120}$ and $\frac{1}{50}$ inch. Throughout these air passages ciliated epithelium is present.

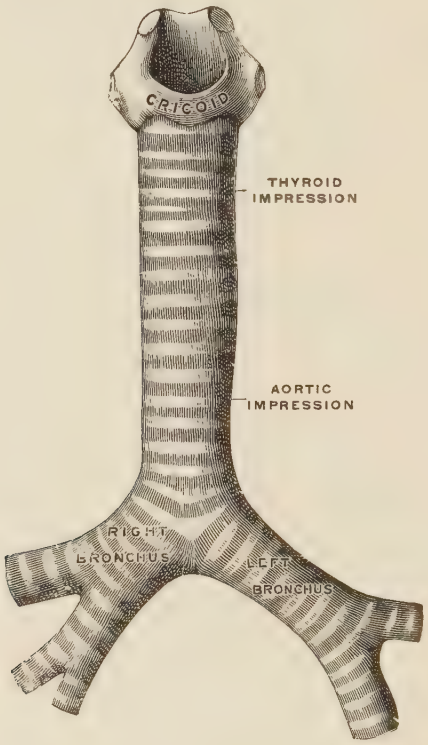


FIG. 271.—Trachea and bronchi, front view. (Testut.)

Alveoli.—Each bronchiole opens into a collection of 8 to 16 alveoli, or air vesicles, called a lobulette, and it is here the actual work of external respiration occurs. The alveoli are from $\frac{1}{70}$ to $\frac{1}{200}$ of an inch in diameter, with walls of a single layer of flat epithelial cells with elastic fibrous tissue. The area covered by their walls is estimated at 90 square meters, or more than a hundred times the area of the skin of the body. Ramifying among the vesicles are the capillaries of the pulmonary arteries.

In these microscopical tissues are the two single layers of epithelial cells through which gases may pass freely, according to the amount of pressure exerted by each gas.

The Lungs.—The ramifications of the tubes with the alveoli and the areolar tissue holding them together constitute the *lungs*.

In shape they are two irregular cones, contained in the thorax, with the bases resting on the diaphragm and the apices reaching into the neck about $1\frac{1}{2}$ inches above the clavicles. (Fig. 239.)

The Mediastinum.—The mediastinum separates the two lungs, and includes all the space in the thorax not occupied by the lungs. It extends from the sternum to the spinal column, and from the upper opening of the thoracic cage to the diaphragm. Four divisions are made, the superior, anterior, posterior and middle mediastinum. The superior is above the pericardial sac; the anterior in front of the same; the posterior behind, and the middle is occupied by the pericardial sac and its contents.

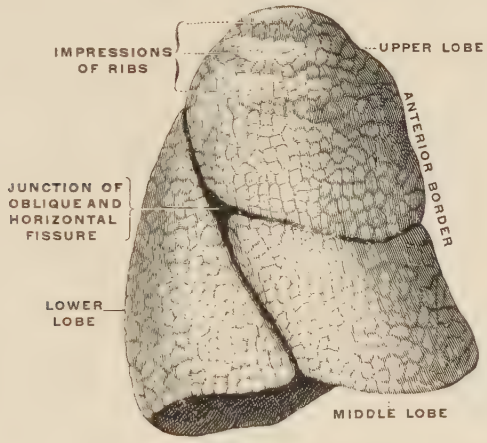


FIG. 272.—Right lung, outer surface. (Testut.)

In the superior and posterior mediastinums are important organs, as the trachea, esophagus, thoracic duct, vagus and other nerves and the great vessels connected with the heart.

The heart encroaches on the space occupied by the left lung. The lungs are covered by a sheet of serous membrane, the visceral layer of the *pleura*, which is reflected upon the chest wall, lining it. This forms the parietal layer of the pleura, which is ordinarily in contact with the visceral layer. A small amount of fluid is secreted which lubricates the surfaces.

The right lung is divided into three lobes, the left lung into two lobes. Each lobe is divided into a number of small areas, $\frac{1}{4}$ of an inch in diameter, called *lobules*, and these are collections of lobulettes. (Fig. 273.)

The lungs are always close to the inner wall of the chest, and their shape changes with changes in the diameters of the thorax.

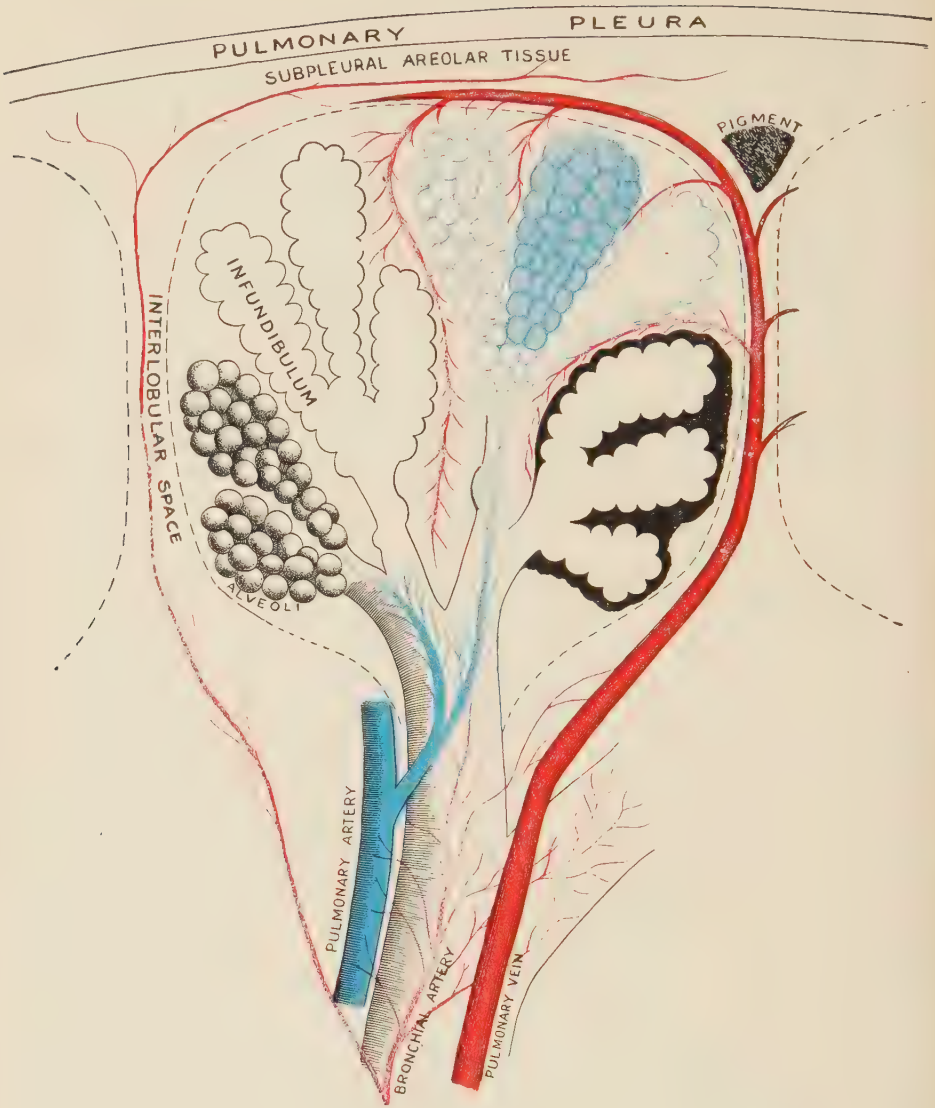


FIG. 273.—Diagram of a lobule of the lung. A bronchiole is seen dividing into two branches, one of which runs upward and ends in the lobule. In the lobule are four groups of infundibula. At the left are two infundibula the alveoli of which present their outer surfaces. Next are three infundibula in vertical section, the alveoli of each opening into the common passageway. Upon the ultimate bronchiole of this group are alveoli. In the next group the first infundibulum shows a pulmonary arteriole surrounding the opening of each alveolus, and the second gives the same with the addition of the close capillary network in the wall of each alveolus. The same arrangement of vessels is seen in the alveolus upon the bronchiole of this group. Around the fourth group is a deep deposit of pigment, such as occurs in old age, and in the lungs of those who inhale coal-dust and the like. On the bronchiole lies a branch of the pulmonary artery (blue), bringing blood to the infundibula for aëration. It also supplies nourishing blood to the tubes and other structures within the lobule. Beginning between the infundibula are the radicles of the pulmonary vein (red), a root of which lies upon the bronchiole. The bronchial artery is shown as a small vessel bringing nutrient blood to the bronchiole (outside of the lobule), the artery and vein, and all of the structures between and around the lobule. No attempt is made to show the sustentacular tissue which occupies the spaces within and around the lobule. (Gerrish.)

Conversely, changes in the shape of the lungs produces changes in the diameters of the thorax.

The Thorax.—The thorax is a cone-shaped cage, partly bony, partly cartilaginous and partly muscular, which contains the two lungs, the heart, the large bloodvessels, the esophagus, thoracic duct, various nerves and glands. (Fig. 274.)

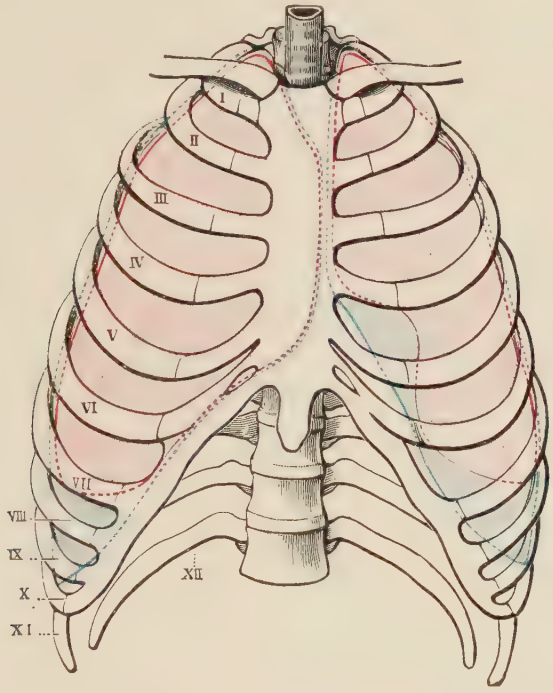


FIG. 274.—Relations of lungs (red) and pleuræ (blue) to the front walls of chest. (Testut.)

The cavity of the thorax is closed, and shut off from the abdominal cavity as well as from the outside, but the interior of the lungs communicates with the outside air by means of the trachea, etc. The atmospheric pressure, thus affects the interior of the lungs, but the walls of the chest prevent it from influencing the outside of the lungs. If the chest is punctured, the lungs immediately collapse on account of the equalization of the pressure outside and within.

When the air enters the lungs, the expansion produced causes them to fill the entire cavity, except where there are other structures. When air leaves the lungs, the chest walls follow the shrinking lungs, and the thoracic cavity is made smaller, but the lungs still completely fill it. There is no vacant space, permanently, in either case.

Normal Position of the Thorax.—The position of the thorax changes continuously during life, but the position at the end of a passive expiration may be considered essentially normal, and forming a starting point from which to estimate the degree of inspiration and expiration. Any enlargement of the thorax from this norm may be considered an active inspiration. Any diminution of the size may be considered an active expiration. A return to the norm after an active inspiration, is a passive expiration and is not caused by muscular effort but by the recoil of the lung tissue after expansion.

THE MECHANISM OF RESPIRATION.

Respiration may be said to begin with the movement of inspiration, in which the diaphragm contracts and increases the diameter of the thorax from above downward. At the same time, the lower ribs are pushed outward, unless the inspiration is forced, in which case they tend to be drawn inward. It is possible the quadratus lumborum and serratus posticus inferior muscles hold the lower ribs from being drawn inward during inspiration.

At the same time the diaphragm is contracting, the scaleni and the external intercostal muscles contract and turn the ribs upward and outward, increasing the diameters of the thorax laterally and from before backward.

These changes in diameter would create a vacuum if the air did not rush to fill the space. If the glottis is open it does fill the entire space so there is no room between the lungs and the chest walls.

The glottis may be closed voluntarily while the chest diameters are being enlarged, with an increase of the physiological effects of inspiration. (See Kellogg's Treatise on Massage, in connection with visceral lifting.)

When the diaphragm contracts, the central tendon descends, pressing upon the abdominal contents, and the abdominal wall bulges out. If the front wall of the abdomen is prevented from bulging, the pressure is transmitted downward, mainly to the pelvic cavity. Following the contraction of the diaphragm and other muscles, comes their relaxation, with an upward push of the dome of the diaphragm and a recoil of the lung tissue which pushes the air out of the lungs, in expiration.

Under ordinary conditions, inspiration is active, expiration is passive. When inspiration is forced, expiration becomes so to some degree.

Active inspiration and passive expiration is called *eupnea.* Forced or labored respiration is *dyspnea,* with the prefix of inspiratory and expiratory, according to whichever is forced. During forced respiration, all the muscles attached to the ribs, all that

hold the scapula firm, and all that fix the abdomen may be called into activity.

Types of Respiration.—These are distinguished according to the parts of the trunk that are especially involved. When the abdominal wall is pushed forward in inspiration, the breathing is called diaphragmatic, or abdominal. When the respiration is mainly carried on by the action of the ribs, increasing the lateral and anteroposterior diameters, with little movement of the diaphragm, it is called costal breathing. This type results from the constriction of the waist. Those who have never worn anything to do this have abdominal respiration as a rule.

The *rhythm of respiration* is about 18 times a minute, or $\frac{1}{4}$ the rate of the heart beat. This rate increases or decreases with that of the heart and temperature.

Inspiration and expiration follow each other with no interval between them, though on account of the passive nature of expiration it seems as though it were much shorter than inspiration. After every six to ten respirations there usually comes one that is distinctly deeper and longer. Ordinarily the depth of respiration varies with its rapidity, faster in shallow, slower in deep breathing.

Ratio of Rate of Respiration, Pulse and Temperature.—The normal ratio between pulse and respiration is 4 to 1. With a normal temperature of 98.6° F. the pulse is 72, the respirations 18 per minute. With each increase of 1 degree in temperature, the pulse increases 10 beats, the respirations $2\frac{1}{2}$.

Sounds of Respirations.—By applying the ear to the chest wall in different localities various respiratory sounds may be heard. Below the clavicle or over the scapula, with each inspiration a sound is heard as of a gentle breeze in distant tree-tops. This sound is produced by the air going into the alveoli, and it is called the "vesicular murmur."

Listening over the middle of the back, the inspired air is passing through the bronchi, and the sound is higher pitched and as though one should blow over the mouth of a bottle. These are the two sounds possible in health.

Relation of Respiration to Circulation.—While the exchange of oxygen and carbon dioxide is the outstanding fact in respiration, there are other very important features connected with it.

In the Chapter on the Circulation reference was made to the suction exerted on the venous blood by the action of the lungs. This is brought about by the difference between the pressures within the thorax and that within the abdomen during respiration.

Intrathoracic and Intrapulmonary Pressure.—The space between the lungs and chest walls is practically *nil*, except during inspiration, but there is a space between the two lungs, the mediastinal space. The pressure exerted upon the contents of this space is the intra-

thoracic pressure, or it is the pressure exerted upon the heart, large vessels, thoracic duct, etc. The pressure in the interior of the lungs, which communicates with the atmosphere, or the intrapulmonary pressure, is that of the atmosphere.

During inspiration, when the thoracic cage increases in all its diameters, so that it is temporarily larger than the contained lungs, the intrapulmonary pressure falls temporarily below that of the atmosphere, or is *minus*, as the air becomes more or less rarefied, according to the amplitude and rapidity of the inspirations, and the size of the opening to the outside.

At the end of inspiration if there is a pause, the pressure rises again to that of the outside atmosphere.

During expiration, the collapse of the chest walls from the relaxation of the muscles of inspiration takes place rapidly enough to compress the air somewhat as it goes out, and a temporary rise of pressure occurs.

When the glottis is closed and a strong *inspiration* taken, the intrapulmonary pressure is much lowered, but if the glottis is closed and an *expiration* is made, the pressure is so much increased it may prevent the emptying of the vena cavæ and pulmonary veins into the auricles. This effect may be observed in the appearance of congestion in the face and neck during violent coughing, straining at stool or supreme muscular efforts of any kind.

Under normal conditions the pressure upon the mediastinal space is negative or minus, for the walls of the thorax are interposed between that and the outside air. If the lungs are fully expanded they are a greater bar to the pressure of the atmosphere, and the intrathoracic pressure becomes more largely a minus quantity than when the lungs are compressed in expiration. But, it is always negative.

Given, therefore, the outside atmospheric pressure exerted on the large veins in the neck and axilla through the skin, and the negative pressure in the mediastinal spaces, the venous blood is bound to go in the direction of the least resistance, that is, into the heart.

Intra-abdominal Pressure.—The pressure within the abdomen varies according to inspiration and expiration. In inspiration, the diaphragm presses down upon the abdominal viscera, the walls of the abdomen, *unless flaccid*, resist the outward pressure, with the net result of increased intra-abdominal pressure. This forces the blood from the inferior vena cava into the thoracic part of the vessel, where the pressure is negative. Thus the suction pump acts on the blood from the lower extremities, pelvic and abdominal regions.

The Relation of Respiration to Abdominal Functions.—The only action of the diaphragm is in inspiration, but that is rhythmic. Below the diaphragm are the stomach and intestines, in whose walls are

smooth muscle tissue. The health of these organs depends upon their functional activity and this is directly aided by the respiratory movements of the diaphragm in exerting a massage action upon them. An intermittent pressure, which is the essence of massage, stimulates the circulation and the peristaltic movements of the abdominal viscera.

If the respiration is mainly costal, this stimulation is lacking, and the viscera are very apt to sag and function feebly.

Pulmonary Capacity.—This indicates the total amount of air contained in the lungs, and is about 330 cubic inches.

Vital Capacity.—Vital capacity is the quantity of air that can be exhaled after making the largest possible inspiration. It can be measured by means of a spirometer, and though subject to error is fairly accurate as a means of testing one's available lung power. A spirometer consists of a graduated cylinder resting in a tank of water. The cylinder is counter-balanced by a weight which allows it to move up and down in the water with the least resistance. A tube passes from outside up into the cylinder chamber, through which the air is blown, so as to cause the cylinder to rise and indicate its amount.

The vital capacity of an average-sized individual is about 230 cubic inches, or 3700 cc. This amount is greater in tall persons, in those with very flexible chest walls, and where the occupation calls for vigorous respiration. Variations in the reading may be due to lack of understanding of the technic involved, inability of the subject to carry out instructions, or to defects in the instrument.

Residual Air.—It is impossible to expel all the air from the lungs, by any effort. That remaining is the residual air, about 100 cu. in.

Tidal Air.—With each quiet respiration, there is a change of some 20 cu. in. This is the tidal air.

Complemental Air.—Complemental air is the amount that can be taken in by a forced inspiration. It is about 110 cu. in.

Supplemental Air.—Supplemental air is the amount that can be forced out by effort and is about 100 cu. in.

THE COMPOSITION OF INSPIRED AND EXPIRED AIR.

Atmospheric air in general consists of 20.96 volumes of oxygen, 79 of nitrogen, 0.04 of carbon dioxide, a variable amount of watery vapor, a small amount of organic material, ammonia, dust, nitric acid, etc.

It varies in temperature from 20° F, below zero to 115° F. above, in the temperate climes, with further extremes possible. Its temperature is modified by passing through the nostrils, so it is more nearly 70° F. when it arrives at the lower air passages.

Expired air has undergone certain changes. Oxygen is 16.02 volumes, nitrogen is 79, CO_2 is 4.38, and it is saturated with watery vapor at a temperature of 98.6° F.

There has been a decrease in oxygen of 4.94 and an increase of carbon dioxide of 4.34 volumes. More oxygen has been lost than shows in the carbon dioxide, but it is supposed some atoms of oxygen have combined with hydrogen and formed water. Body heat is lost by this elimination of water after its conversion from a liquid to a gaseous state.

It does not seem possible to say just how much carbon dioxide is necessary to make air unfit to breathe. A proportion of 4 per cent in a confined place causes definite symptoms of distress, but a fairly good rule is to try to get out of air that, to one just coming from fresh open air, has an offensive smell.

THE EXCHANGE OF OXYGEN AND CARBON DIOXIDE.

There are three forces effecting the exchange of these elements.

1. The movements of inspiration and expiration.
2. The changing size of the heart.
3. The diffusibility of gases.

The first two forces result in the variation of intrapulmonic and intrathoracic pressure, which causes the alternate ingress of air rich in oxygen and the egress of air charged with CO_2. The diffusibility of gases effects the exchange in the alveoli and in the microscopical cells of the body.

In a mixture of gases, each presses according to its volume. When oxygen has 21 volumes, it presses into the lungs with more force than when it has but 16 volumes, as in expired air.

If a membrane is interposed between two gases of different volumes, that with the higher pressure would go through until the pressure is equalized on both sides of the membrane.

In the lungs, this permeable membrane is the single layer of epithelial tissue in alveolar and capillary walls, and through this the oxygen is going from the outside. The red corpuscles load up with it. When the carbon dioxide arrives with a pressure of 4.38 it goes through the membrane because the CO_2 in the atmospheric air has less pressure, so the CO_2 is expelled.

The arterial blood passes to the tissues nearly saturated with oxygen. In the systemic capillaries the pressure of O is much greater than is that in the cells, so it is given off to the cells. In the cells, CO_2 is constantly being formed and its pressure is higher than in the blood and lymph in the neighborhood. It therefore passes into the blood and is carried off.

As the blood goes through the capillaries CO_2 is given off from the cells. A small part is absorbed by the plasma, but most of it

combines with sodium and potassium to form bicarbonates. The materials of which these are formed come from the hemoglobin. As the hemoglobin gives up O to the tissues, its acidity lessens, so it is more ready to release alkaline substances. The CO_2 goes to the lungs firmly combined as bicarbonates. In the lungs the hemoglobin taking up O becomes more acid, and this causes a breaking-down of the bicarbonates and the liberation of CO_2 to pass out of the lungs.

THE INNERVATION OF THE RESPIRATORY MOVEMENTS.

The diaphragm is supplied by the phrenic nerve, and branches of the cervical and brachial plexi supply the other muscles of inspiration, while branches of the lumbar plexus supply the abdominal wall. The facial nerve supplies the nose, and the vagus, the larynx. The muscles concerned are all voluntary, so respiration may be increased or decreased at will. But, the ordinary movements occur without conscious control through centers in the medulla. This center is apparently self-sufficient and sends out the impulses that coördinate the muscles concerned. The rate is varied according to the needs of the organism. It may be that the accumulation of carbon dioxide in the blood serves as the stimulus to the center in the medulla, but, the normal rhythm of 15 to 18 per minute goes on, day and night, waking or sleeping.

Muscular activity, emotions, sleep and temperature vary the respiratory depth and rate.

QUESTIONS.

What is respiration and where does it take place?
What is the mediastinum?
What is "intrathoracic pressure?"
What is "intrapulmonary pressure?"
What are the boundaries of the lungs?
In what way does the oxygen of the air get to the tissue cells?
How does the CO_2 produced in the body get out?
What is the relation of respiration to circulation?
What is the relation of respiration to digestion?
Describe vital capacity.
How does expired air differ from inspired air?

CHAPTER XI.

THE DIGESTIVE SYSTEM.

THE COMPOSITION OF THE BODY.

Various parts of the body have been considered as to their form and structure. It has been shown that all the diverse forms of which the body is composed may be placed into five classes of tissue cells.

These tissue cells may again be examined to see of what elements they are composed, and it is found that the same elements are present in each in varying amount and arrangement. Consideration has been given to the combination of organs that form the mechanism by which may be carried to them, for their up-building, repair and functioning, the substances of which the cells are made. Another mechanism provides for the gaseous requirements of the cells.

With both the above mechanisms the blood is the purveyor of the substances needed by the cells, air, water and food. These must be taken into the blood before they can serve the cells. Air and water are ready for immediate use, but food must undergo many processes before it can become a part of the blood. Food is needed for growth and repair, to maintain the heat of the body and to provide its energy.

Of all the materials needed, the most vital is air. Without it, we would die in a few minutes. There is more air available in the world than anything else.

The next in urgency is water, as without that, death ensues in a few days. The least urgent of the three is food, as persons have gone more than six weeks without food and survived.

The indication for the need of water is thirst, which is usually located in the mouth and throat, but water in the mouth does not relieve thirst. Water introduced into the circulation, will. The sensation of hunger for food is referred to the stomach, but hunger is felt if the stomach is removed, and the sensation is relieved by feeding per rectum. It is thus seen that hunger and thirst are the calls of the *tissue cells* for food and drink. The amount of food, drink and air needed varies greatly according to the surrounding temperature, activity and age of the individual.

THE COMPOSITION OF FOODS.

Of foods there are many, but on analysis they are found to consist in varying proportions of

Water.
Mineral matter.
Protein.
Carbohydrate.
Fat.

The body is made up of these same elements (see the Composition of the Plasma in Chapter II), with many compounds, both solid and liquid, organic and inorganic.

Water.—This forms about 70 per cent of the body-weight. It acts as a solvent in the body and renders materials capable of absorption. It is a constituent of every tissue, and in varying proportions, it is in every kind of food.

Besides the amount taken in an ordinary diet, about 3 pints daily are considered necessary. This may be increased or decreased according to the activity, temperature and food taken.

The Inorganic Compounds.—These are formed from some fifteen chemical elements. Upon their correct proportion and balance depend the health and efficiency of the organism.

These elements, with their percentages as occurring, are as follows:

	Per cent.
Calcium	1.300
Carbon	13.500
Chlorine	0.085
Hydrogen	9.100
Nitrogen	2.500
Oxygen	72.000
Phosphorus	1.150
Potassium	0.026
Sodium	0.100
Sulphur	0.147
Fluorine, Iodine, Iron, Magnesium, Silica	Small and varying quantities.

Of these elements, calcium forms three compounds—the carbonate, the fluoride and the phosphate. In the blood the carbonate is combined with CO_2. All three give to the bones and the teeth their solidity and hardness.

Sodium provides four compounds—the carbonate, the chloride, the phosphate and the sulphate.

Sodium chloride is very abundant, being in every tissue of the body, but especially in the blood. It is instrumental in the diffusion of liquids. Water gets into the blood mainly on account of

the contained sodium chloride. The carbonate and phosphate, also in every tissue, imparts alkalinity to them.

Potassium forms three compounds—the carbonate, the chloride and the phosphate. These are usually associated with the sodium compounds and have similar effects.

Magnesium has the carbonate and the phosphate—the former in the blood, while the latter forms a part of all the tissues.

Iron is a constituent of hemoglobin.

Iodine is combined with materials in the thyroid gland, as its internal secretion. It is also in the liver, bile, small intestine, blood and lungs.

Numerous other compounds are formed during the life processes, as acetic, hippuric, lactic, oxalic and uric acids; alcohol, glycerin, cholesterin, urea, creatin, bilirubin, indol, etc.

Various forms of malnutrition follow the absence of these salts from the dietary. They should always be left in the food, though modern methods of refining frequently result in robbing it of these necessary elements.

The Organic Compounds.—These are *protein*, *carbohydrate* and *fat*.

Chemically, *protein* consists of carbon, hydrogen, oxygen, nitrogen and sulphur, in varying proportions, with more or less phosphorus and other inorganic salts.

Many forms of protein exist, some of which are not represented in the human body. Some are relatively simple in structure; others very complex.

In general, proteins cannot pass through an animal membrane; they can be coagulated and, under the influence of bacteria, in a warm, moist atmosphere, with oxygen, they will decompose and putrify. These processes result in the formation of simpler compounds, as hydrogen sulphide, carbon dioxide, ammonia, nitrates and phosphates.

In the presence of acids, alkalies and enzymes (ferments), protein break up into amino-acids and diamino-acids, which appear to be their ultimate divisions. These nitrogen-holding bodies, of which some twenty different combinations have been isolated, include alanin, arginin, cystin, glycocoll, histidin, leucin, lysin, tryptophan, tyrosin, etc.

Proteins constitute 20 per cent of muscle and 30 per cent of osseous tissue.

According to their structure, a division of proteins is made into "simple," "conjugate or combined" proteins and protein derivatives.

The *simple proteins* include:

1. *The Albumins.*—These are soluble in water, in a normal saline solution and in a saturated solution of sodium chloride and magnesium sulphate. They can be coagulated by heat.

Serum albumin, is found in the blood, lymph and chyle.
Egg albumin, resembles serum albumin, but is not found in the human body.
Lac albumin, is the albumin of milk.
Myo-albumin, is in the muscle plasma.

2. *The Globulins.*
Serum globulin, a constituent of serum.
Fibrinogen, the antecedent of fibrin, in the blood plasma.
Myosin and *myogen*, in the muscle plasma.
Globulin, in the crystalline lens of the eye.

3. *The Albuminoids.*—These include:
Collagen, in fibrous connective tissue.
Ossein, in osseous tissue.
Chondrigen, in cartilage.
Elastin, in elastic fibrous tissue.
Keratin, in hair, nails, etc.

4. *Phospho-proteins.*—Containing phosphorus.
Caseinogen, in milk.
Vitellin, in egg-yolk.

Conjugate, or *Combined Proteins.*—In these compounds the protein is united with other substances as carbohydrates, nuclein and coloring matter.

Hemoglobin, *mucin* and *nucleo-protein* are in this group. Nucleins when decomposed yield the *purin* bases, as xanthin, adenin, guanin, etc.

The Protein Derivatives.—These represent the proteins as they step down in complexity during the process of digestion under the influence of enzymes. They include *acid-albumin*, *alkali-albumin*, *proteoses*, *peptones* and *polypeptids*.

The Carbohydrates.—These are mostly starches and sugars. They are composed of carbon, hydrogen and oxygen. The atoms of carbon are always six or some multiple of six. The hydrogen and oxygen are in the same proportion as they are in water.

The *starches* include those found in grains, vegetables and fruits. *Amylose* is a general name for them.

Glycogen is a starch in the liver cells and muscles.

Dextrin is an intermediate product between starch and sugar.

Cellulose is the framework of vegetable cells.

The *sugars* include:

Dextrose ($C_6H_{12}O_6$), glucose, or grape sugar, is absorbable sugar, as present in the blood, liver and muscle tissue.

Levulose is fruit sugar.

Lactose is the sugar in milk.

Maltose is the sugar in malt, derived from starch.

Saccharose is cane or beet sugar.

Dextrose is the only form of sugar that can be used in the body.

The others must be transformed or inverted into dextrose before they can be absorbed.

The Fats.—These are also compounds of carbon, hydrogen and oxygen, but the proportion of oxygen is very small as compared with those of carbon and hydrogen. *Stearin,* the hardest fat has composition $C_3H_5(C_{18}O_{35}O_2)_3$.

In man, fat is found in the subcutaneous tissues, around viscera, in the yellow marrow and in milk.

THE NEED FOR REPAIR AND REPLACEMENT OF MATERIALS.

The cells of some organs have relatively long resting periods between the working periods. Others have only momentary times for rest. But, whether they are actively at work or practically resting, the life processes involve a constant breaking down of the tissue cell.

The fact that an animal given adequate water but no food progressively loses weight is sufficient evidence of a constant need for repairs and replacement of materials in the living body, varying according to the activity undergone.

The carbohydrates and fats break down in producing heat and other forms of energy, and the proteins that have been used in the framework of the cells break down by use, just as the parts of a house do in the process of time. These substances are replaced by food and no substitutes have yet been discovered for it. The food we eat is converted into the bodies we use.

THE PROCESSES IN CONVERTING FOOD INTO THE HUMAN ORGANISM.

It is interesting to observe the history of the food that is going to be made into a human being, and study the relationship between the methods of procuring food in these modern times and the necessity for taking formal gymnastics or learning to play games.

In the primitive races, food meant either the chase, the laborious tilling of the soil or the care of flocks and herds, except in the tropics where food grew with little effort on the part of man.

A piece of meat to eat had to be cut from an animal; perhaps, the animal had to be caught and killed; the wood for the fire to cook it had to be gathered; the water in which it was cooked had to be carried from the spring. No matches being available, fire was made by laborious processes, and perhaps stones had to be heated and rolled into the pot to heat the water enough to cook the meat.

The head of the family that attended to getting such a meal did not need to go to "gym" classes to keep *fit.*

Now, the specialization of work of modern days is seen. We decide to have chops for dinner, and a telephone order to the butcher

shop bring the articles to the kitchen door. A match to the gas-stove broiler, and attention to the matter for rather less than ten minutes makes the chops ready to eat. Have we the appetite that primitive family had for their meat? Does it taste as good and does it digest as well as for that other family? But, then how many people helped us get our chops? How many were concerned in the telephone; in the stock farm that raised the lamb; in the stock yards, where it was prepared for market; in the making of the retail butchers' shop; in the motor cars that delivered it; in making the gas for fuel and the stove for burning the gas; the salt and pepper that seasoned the chops, and the dishes from which it was eaten?

If the above processes are elaborate they are not more so than the various stages through which food passes before it becomes a part of our structure.

These processes may be grouped as:

1. Prehension or taking the food in the hands to put it in the mouth.
2. Mastication, or chewing by which it is divided and subdivided into small particles.
3. Deglutition or swallowing, which passes it along from the grinding room to the next station.
4. Gastric digestion, or the mechanical and chemical changes that it undergoes in the stomach.
5. Intestinal digestion, or the mechanical and chemical changes it undergoes in the intestine.
6. Absorption or its taking up by the lymphatic vessels to be carried to the venous system, and then to the heart.
7. Cell assimilation, or the building-up into the cell structure, which is the final step by which food becomes truly a part of one's self.

Foods which cannot yield energy are not affected chemically, but are dissolved if not already in solution, and discharged from the body in the same state as when received. Food which yields energy must be separated from the innutritious parts, and go through various changes.

THE CHEMICAL CHANGES IN DIGESTION.

These are effected by the presence of certain substances called "enzymes." Various observers have given different definitions to this term. Oppenheimer suggests the following:

"An enzyme is a substance produced by living cells which acts by catalysis. The enzyme itself remains unchanged in this process, and each enzyme exerts its activity only upon substances whose molecules have a certain definite arrangement."

Enzymes act to the best advantage at the body temperature, but are destroyed in a high temperature. They never completely convert the substance upon which they act. If these substances are removed as fast as formed, the enzyme keeps on acting.

Enzymes are divided into many classes according to the substances acted upon by them. The principal of these, according to the food affected, are:

1. The proteolytic or protein-splitting enzymes. They cause a hydrolytic splitting of the protein molecule.
2. The amylolytic or starch-splitting enzymes. They cause a hydrolytic splitting of the starch molecule.
3. The lipolytic or fat-splitting enzyme.
4. The sugar-splitting enzymes. Two groups of these, one of which converts the double sugars into the single sugars or monosaccharids; the other splits the monosaccharids.
5. The coagulating enzymes which convert soluble into insoluble proteins.

Of the above group the proteolytic enzymes include:

Pepsin, in the gastric juice, which converts proteins into peptones and proteoses.

Trypsin, in the pancreatic juice, which splits proteins into their constituent amino-acids.

Erepsin, in the small intestine, which splits peptones and proteoses into their constituent amino-acids.

The amylolytic enzymes include:

Ptyalin, in the saliva, which converts starch to sugar (maltose).

Amylase, in the pancreatic juice, which converts starch to sugar (maltose).

Liver glycogenase, in the liver, which converts glycogen to dextrose.

Muscle glycogenase, in the muscles, which converts glycogen to dextrose.

Invertase, in the small intestine, which converts cane sugar to dextrose and levulose.

Maltase, in the small intestine, saliva and pancreatic juice, which converts maltose to dextrose.

Lactase, in the small intestine, which converts lactose to dextrose and galactose.

The fat-splitting enzymes include:

Lipase or *Steapsin,* in the pancreatic juice, fatty tissues, blood, etc., which splits neutral fats into fatty acids and glycerin.

The hydrolytic action of an enzyme consists of a molecule of the affected substance, in the presence of an enzyme, taking up water and subsequently splitting the new molecule into two or three simpler ones.

THE ORGANS CONCERNED IN DIGESTION. THE ALIMENTARY CANAL AND ACCESSORY ORGANS.

The process of digestion is begun in the mouth and finished in the small intestine. To all intents and purposes the alimentary canal may be considered as a tube passing through the body from the mouth to the anus, and the food in it should be considered as outside the body until it is taken up from the tube by absorbent vessels.

The alimentary canal begins with the mouth, it continues through the esophagus, stomach, small intestine and large intestine. Accessory organs to the canal, are the teeth, tongue, salivary glands, gastric glands, intestinal glands, liver and pancreas.

These will be considered in order, before taking up the kinds of food presented to them for preparation.

The Mouth.—This is an irregularly oval aperture, formed by the superior maxillary bone, the mandible and the cheeks, and limited and closed in front by the lips. Its floor is formed by the tongue. It communicates posteriorly with the pharynx, superiorly with the naso-pharynx and inferiorly with the esophagus and larynx.

It contains the teeth and the tongue and has opening into it the ducts from three pairs of salivary glands.

It is lined with mucous membrane, which with the salivary secretion keeps the mouth moist and aids in the appreciation of taste. Articulate speech is assisted by the mouth and its accessories. This cavity serves as a chamber in which mastication and insalivation of food can take place. The cheeks by the contraction of the muscles in their walls help to move the food around, and the lips keep it from falling out of the mouth.

The hard palate forms the roof of the mouth with the soft palate attached to its posterior border. Dangling from the center of the soft palate is a process called the *uvula*. (Fig. 275.) This is concerned in articulation. The imperfect development of the palate bones, resulting in what is known as "cleft palate" or "hare-lip" is a serious impediment to speech.

The Teeth.—These are hard white structures set in the margins of the superior maxilla and the mandible. They are for biting, tearing and grinding the food, the different groups having these special uses.

The teeth grow in two sets, one in infancy, the other in childhood and youth. The first set is superseded by the second, and so is called the *temporary* or *milk* teeth. The second set is called the *permanent* teeth.

In the first set are 5 teeth in each half of each jaw, or 20 in all. Beginning at the middle line, there are 2 incisors, 1 canine and 2 molar teeth. They erupt about the seventh month, and the full

20 are usually through by the end of the twenty-fourth month. The teeth in the lower jaw usually precede those of the same group in the upper jaw. The order of eruption is: (1) The central incisors;

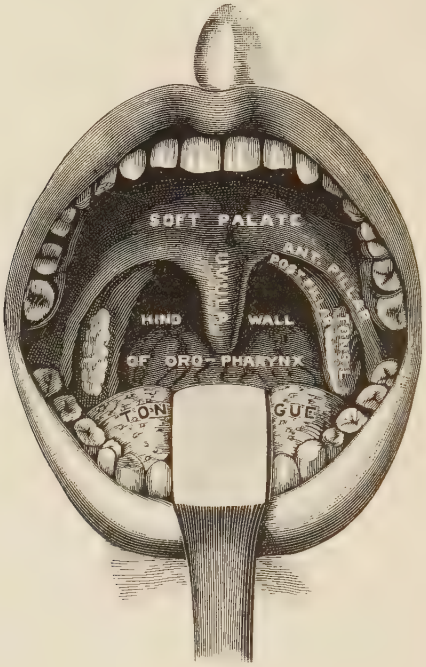


Fig. 275.—The soft palate and tonsillar regions. (Testut.)

Fig. 276.—The teeth of the right half of the upper jaw in their sockets, viewed from below. (Gerrish.)

(2) the lateral incisors; (3) the first molars; (4) the canines; (5) the second molars.

About the sixth year a molar tooth develops, which is the first of the permanent set. It is called the "six-year molar." About the seventh year the temporary set begins to be shed and is replaced by the permanent teeth. The 2 molars of the milk set are replaced by 2 bicuspids of the permanent set. The third molar is not developed until late adolescence and is popularly called the "wisdom tooth." (Fig. 276.)

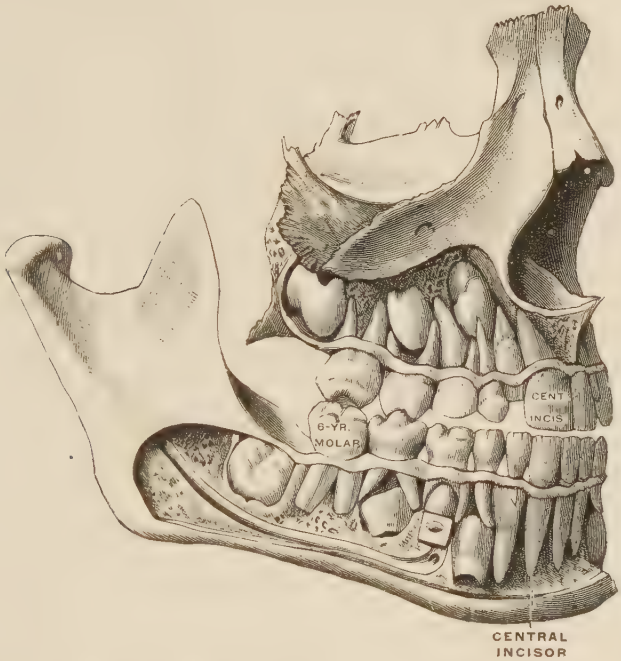


FIG. 277.—The jaws of a child of seven and a half years, the external table of bone having been cut away to show the stage of second dentition. (Testut.)

The temporary teeth are replaced by the permanent set at about the following years.

First molar, sixth year.
Two middle incisors, seventh year.
Two lateral incisors, eighth year.
First bicuspids, ninth year.
Second bicuspid, tenth year.
Canines, eleventh to twelfth year.
Second molar, twelfth to thirteenth year.
Third molar, seventeenth to twenty-first year.

The replacement of one set by the other occurs by the later-

coming teeth in their growth absorbing the roots of the milk teeth, until only the crown remains. Little force is then needed to remove that. (Fig. 277.)

Parts of a Tooth.—A tooth is composed of three parts, crown, root and neck. The crown is the part that projects from the gums; the root is imbedded in the alveolar process of the jaws; and the neck is the slightly constricted part that is just under the gums. (Fig. 278.)

The crown is composed of *dentin,* covered with enamel. Enamel is a form of epithelial tissue with the cells calcified and is the hardest material in the body. The root tapers and fits into the bony sockets very neatly, so as to avoid uneven pressure.

In the tooth is a central cavity or pulp chamber. The pulp consists of a nerve (branch of the trifacial or fifth) bloodvessels and cells in an areolar mesh.

The sockets of the teeth are lined with a form of periosteum, called the pericementum, which is reflected on to the root of the tooth as far as the neck.

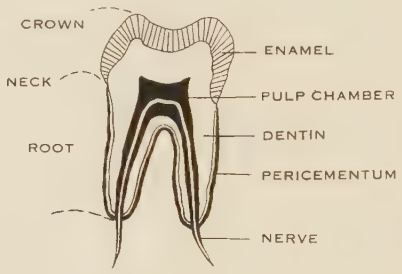


Fig. 278.—Diagram of the structure of a tooth.

The Uses of the Teeth.—Teeth aid in phonation and add to the attractiveness of the features, as well as helping to preserve the contour of the face. The front teeth are for cutting food, while the back teeth serve as grinders. The surfaces of the upper molars fit in with those of the lower jaw, each tooth being in contact with two opposite ones. The lower jaw moves on the upper in a side to side, antero-posterior and an up-and-down movement. Various muscles attached to the jaws, the hyoid bone, the sphenoid and the temporal bone are concerned in these movements.

This grinding or mastication is aided by the tongue, lips and cheeks, which hold the food in contact with the teeth, and these with the saliva to moisten the food, initiate the process of digestion. The more thorough the mastication, the more finely the food is divided, the better can the digestive juices get at it.

A harmonized action of sensory and motor nerves informs the

brain of the condition of the food in the mouth, and transmits the orders for the continuation or suspension of mastication and insalivation.

The sensory nerves are fibers of the trigeminal and the glossopharyngeal.

The motor nerves are motor fibers of the trigeminal, the hypoglossal and the facial. The nerve centers are in the medulla.

The action of the muscles of mastication is voluntary, though it continues after the attention has been diverted. Apparently, by reflex action, the messages as to the state of the food, result in continued activity, either in chewing or swallowing.

The Tongue.—The tongue is a muscle, very mobile, changing in length and width at every contraction. It is an organ of the special sense of taste; an organ of speech, and assists in mastication, insalivation and deglutition. It is about $3\frac{1}{2}$ inches long, covered with mucous membrane under which is a layer of fibrous tissue.

The upper surface is rough by reason of many papillæ. Their size varies, the smaller ones being in front, and a few (8 to 12) large ones or *circumvallate papillæ*, toward the back. (Fig. 236.)

Most of the taste-buds are found in these circumvallate papillæ.

The nerve supply, other than the gustatory nerve, is from the fifth and twelfth cranial nerves.

There are many nerves of ordinary sensation in the tongue, so it is very sensitive. It gives information to the brain as to the size of the mass in the mouth and the stage of mastication reached.

Salivary Glands.—There are three salivary glands on each side.

The *parotid*, largest in size, is beneath and in front of the lobe of the ear. Stenson's duct carries the secretion.

The *submaxillary* is below the mandible, near the angle of the jaw.

The *sublingual* is under the mucous membrane of the mouth lateral to the middle line in front. The average amount secreted in twenty-four hours is much over a liter. This is of alkaline reaction.

These glands all have ducts which open near the teeth, their secretion, *saliva*, being mixed with that from numerous mucous glands of the mouth. Their flow is increased by mastication and by the smell of appetizing food. (Fig. 279.) Saliva not only moistens the food, but it contains the digestive ferment, *ptyalin*. This ferment begins the digestion of the starches of the food. The more thorough the mastication and insalivation of the food, the more nearly is the starchy element digested.

Starch, especially cooked starch, plus water, in the presence of *ptyalin*, takes up a molecule of water and breaks into a soluble starch, which then splits into maltose and dextrin. The further conversion of maltose into dextrose takes place in the small intestine.

Saliva also aids in the appreciation of taste by keeping moist the tongue and mouth, and in phonation by the same means. The

dry tongue cleaves to the roof of the mouth and one is speechless in consequence.

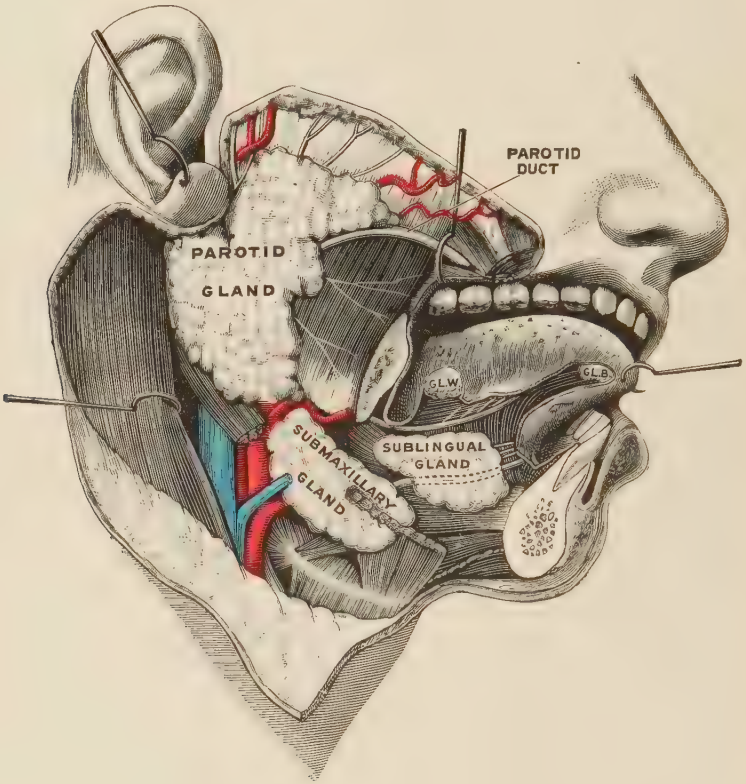


FIG. 279.—The salivary glands. The right half of the body of the mandible has been removed. GL. W., gland of Weber; GL. B., gland of Blandin. (Testut.)

The Tonsils.—Though the tonsils have no special relation to the digestive process, they will be considered here as connected with the mouth.

The tonsils are two ovoid bodies of varying size at the entrance to the pharynx between the anterior and posterior pillars of the fauces. (Fig. 275.) They are a collection of lymph nodules, covered by a capsule of fibrous tissue which sends trabeculæ into its substance and divides the tonsils into many compartments. The surface next the fauces has 12 to 15 depressions or crypts which extend into the tonsil.

Mucous glands open into these crypts and with their secretion is mingled great numbers of lymph cells.

The function of the tonsils is not understood. Apparently, they

absorb and destroy pathogenic bacteria, if they are in a healthy condition, but if enlarged and hardened they seem to be a source of infection themselves. In the fevers of children they become con-

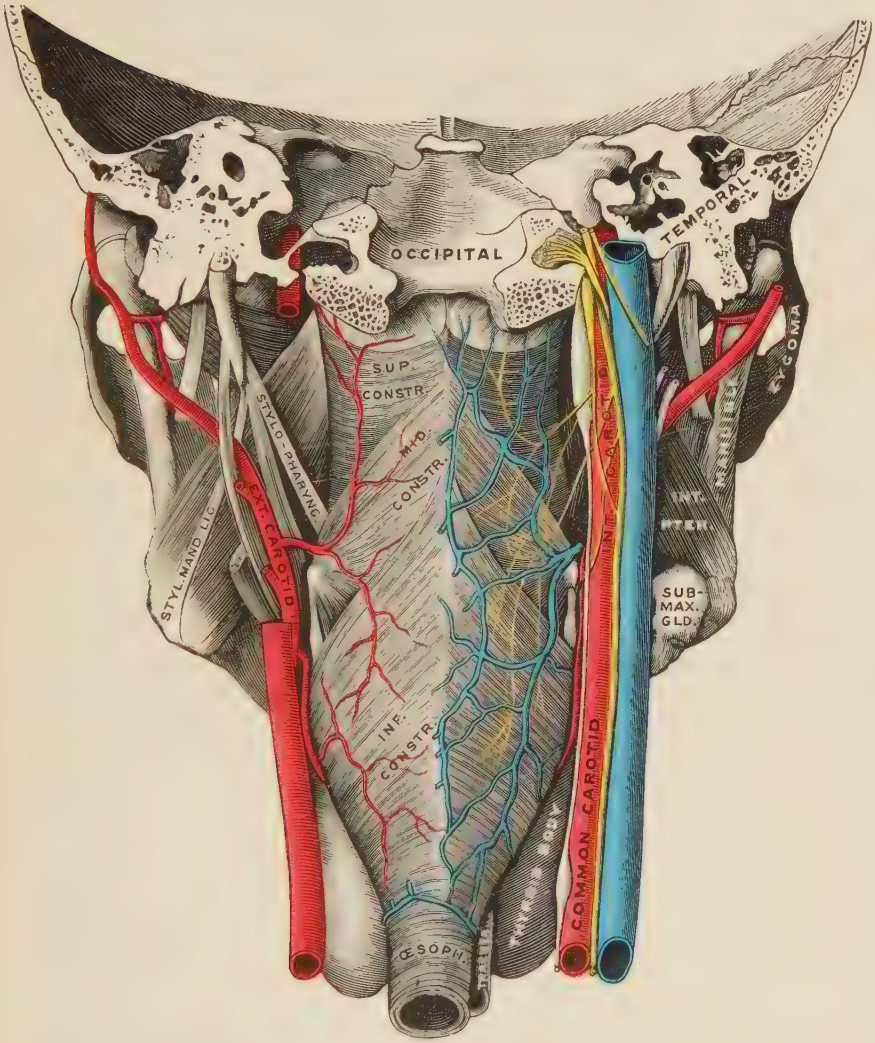


FIG. 280.—Muscles of the pharynx, viewed from behind, together with the associated vessels and nerves. (Modified from Testut.)

gested and enlarged. It is possible their protective function may end at the age of puberty, at which period a child becomes less liable to the infectious fevers.

Deglutition.—After the food has been thoroughly masticated and insalivated, deglutition follows with almost no effort. If the preceding processes have not been well performed, there must be a definite muscular effort to swallow the bolus of food, which is done by the aid of the constrictor muscles of the pharynx. (Fig. 280.)

Deglutition requires an elaborate series of coördinated movements in which the food is carried from the back of the tongue, through the pharynx, into and through the esophagus and then into the stomach. It is also prevented from going backward into the nose or into the larynx. The action is partly voluntary, partly reflex, the different coördinations occurring through centers in the medulla.

The Esophagus.—The esophagus is a tube, 9 inches long, $\frac{1}{2}$ to $\frac{3}{4}$ of an inch in diameter, which extends from the pharynx to the cardiac orifice of the stomach, passing through the diaphragm on its way. It lies behind the trachea.

The coats of the esophagus or gullet are muscular and epithelial. The upper part of the muscular coat is of striated muscle, therefore under the control of the will. Further down there is a mixture of striated and plain muscle while at the lower part, only plain muscle tissue is found.

Liquids pass down the esophagus with no apparent effort, as though dropped. Solid or semi-solid food requires a peristaltic movement in the lower part of the tube.

A peristaltic movement implies inhibition of circular fibers in front of a bolus of food, so it may pass forward by the contraction of fibers behind it.

The movements of the middle and lower parts are involuntary and vermicular, moving the bolus of food toward the stomach. From this point, the work of digestion is carried on below the diaphragm or in the abdominal cavity. Only a few of the organs in the abdomen are not concerned in digestion.

The Abdominal Cavity.—The abdomen is the cavity in the lower part of the trunk, between the diaphragm above and the brim of the pelvis below.

It is bounded in front and on the sides by a muscular wall which includes the rectus abdominis, obliquus externus abdominis, obliquus internus abdominis, and the transversalis muscles. On the posterior lateral walls are the quadratus lumborum, psoas magnus muscles and the iliac fossa, while the vertebral column is posterior. The dome of the diaphragm extends as high as the fourth rib, varying according to the respiratory movements.

The shape of the abdomen varies according to age and sex. In infancy, it resembles an inverted, truncated cone. The adult female is the reverse, with the male type more barrel-shaped with a flattening antero-posteriorly.

The cavity is lined with serous membrane, called the *peritoneum*.

This is reflected on to the viscera and enables the different organs to slip and slide a short distance without friction. The organs contained in the cavity are: The stomach, liver, spleen, pancreas, 2 kidneys, 2 suprarenal bodies, the small intestine, the large intestine (except the rectum), abdominal aorta, and its branches, the inferior vena cava, the beginning of the thoracic duct, the vagi, sympathetic ganglia and nerves, besides numerous lymph nodes. For convenience in describing the structures contained in the cavity, the abdomen is divided into nine regions, though anatomists are not agreed as to the boundaries of them.

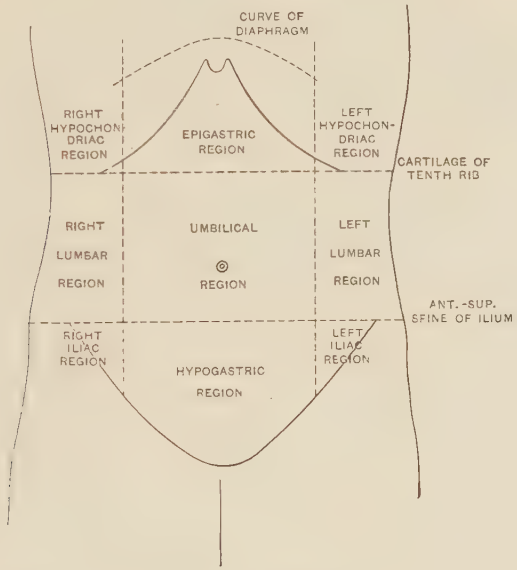


FIG. 281.—Regions of the abdomen according to the method of Gerrish.

Following the arrangement described in Gerrish's *Anatomy*, two transverse planes cut the abdomen. One of these is at the level of the tenth costal cartilage, the other at the level of the anterior-superior iliac spines. This forms three zones, the subcostal above, the umbilical in the middle and the hypogastric below. These zones are divided by two sagittal planes passing through the middle of Poupart's ligament.

Thus the abdomen has the umbilical region around the umbilicus, the right and left lumbar on either side of it. The epigastric region is above the umbilical, with the right and left hypochondriac on either side. The hypogastric is below the umbilical, with the right and left iliac or inguinal on either side. Apparently this leaves nothing in the hypochondrical regions, but it should be remembered

that the diaphragm comes upward, so that there is a greater space than appears on the surface. (Fig. 281.)

The Stomach.—The stomach is a pear-shaped viscus, located in the epigastric and left hypochondrium. Food enters it at the *cardiac orifice*, just below the diaphragm to the left of the middle line of the body, and leaves it from the *pyloric orifice* somewhat lower down and to the right of the middle line.

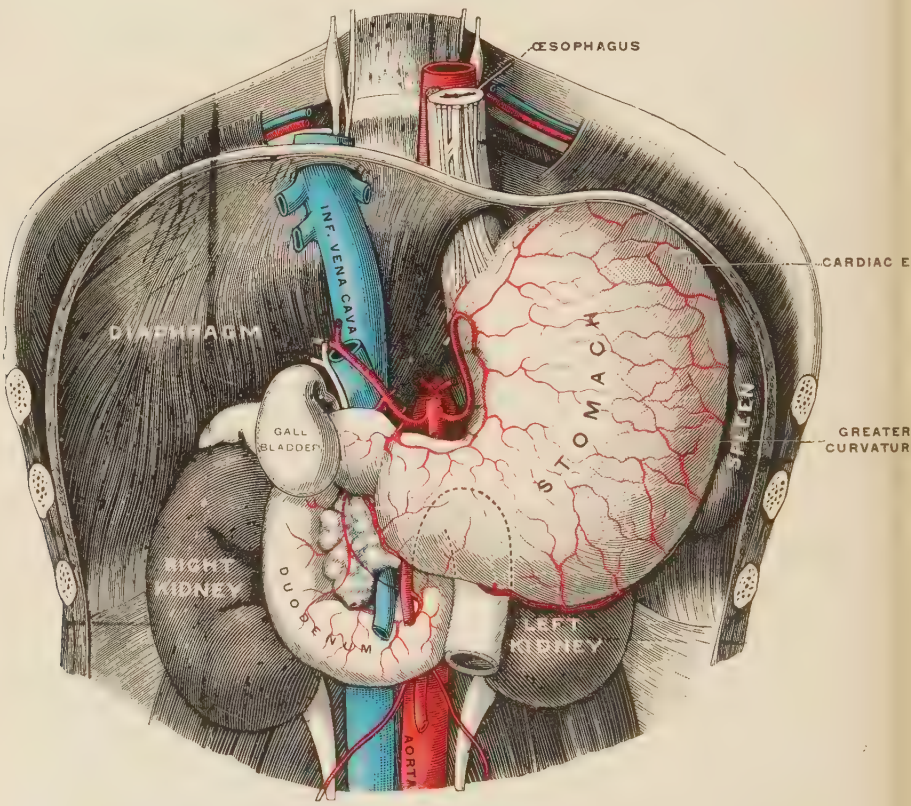


FIG. 282.—Stomach and duodenum, the liver and most of the intestines having been removed. The pyloric end of the stomach should be represented as turned directly backward. (Testut.)

The expanded end of the stomach is the *fundus*. Except during the passage of food from the esophagus, the cardiac orifice is kept closed by the "sphincter cardiæ." During gastric digestion the pyloric orifice is closed except when it allows digested food to pass out.

Between these two orifices, superiorly, the line of curvature of the stomach is called the "lesser curvature." The long way around, between the two is the "greater curvature." (Fig. 282.)

The stomach is variable in size, according to its contents. When empty the anterior and posterior walls are in contact with each other. When it is distended, its greatest length is about 14 inches, its transverse diameter 5 inches, and its capacity is some 5 pints.

The stomach is nearly vertical when empty. When distended the pylorus is moved 2 inches toward the right and the greater curvature is tilted toward the front. It exerts considerable pressure upward on the diaphragm, with more or less consequent interference with the action of the heart.

FIG. 283.—Diagram to show the direction of the fibers in the three muscular layers (Testut.)

The Coats of the Stomach.—Four coats invest the stomach, the serous or peritoneum, the muscular, the submucous and the mucous.

The peritoneal coat covers the stomach, front and back, passing from the lesser to the greater curvatures. The two layers fall free from the lower border, forming a fold like an apron, which covers the intestines. Doubling back it wraps the transverse colon.

This is the *great omentum.* It contains more or less fat and serves to protect the intestines from cold.

Muscular Coats.—The muscular coat varies in thickness from $\frac{1}{50}$ of an inch over the cardiac end to $\frac{1}{12}$ of an inch at the pylorus. It consists of three layers of unstriated muscle. The outer layer is longitudinal, the middle layer circular, and the inner layer oblique in direction. (Fig. 283.)

The muscular fibers increase in thickness at the pyloric end so they form a thick ring-like sphincter called the *pylorus*, with a similar thickening at the cardiac orifice called the "sphincter cardiæ."

In the muscular wall are two groups of autonomic nerves, the plexi of Auerbach and of Meissner. Similar groups are found in the muscles of the intestines.

The Submucous Coat.—This is a layer of loose-meshed areolar tissue, in which the larger bloodvessels and nerves are imbedded, protecting them from pressure and allowing free movement between the muscular and mucous coats.

Mucous Coat.—This is $\frac{1}{25}$ of an inch thick, consisting of columnar epithelium, resting on a basement membrane. The mucous membrane is divided into numerous polygonal depressions from the bottom of which extend gastric glands. (The honey-comb tripe of the markets illustrates these depressions in a larger way.)

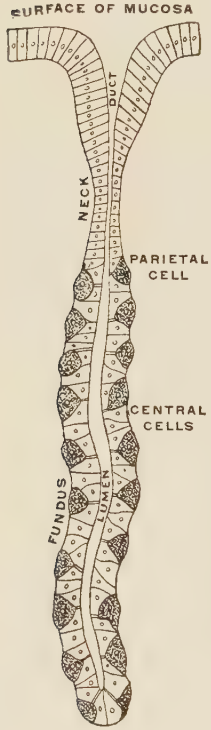


FIG. 284.—Cardiac gland in longitudinal section. (Gerrish.)

Gastric Glands.—The gastric glands are tubular and secrete the gastric juice which contains *pepsin, rennin, lipase* and *HCl.*

The glands nearest the pyloric end secrete mostly pepsin, while those at the fundus (large end), secrete both acid and pepsin. (Fig. 284.)

Gastric Juice.—The gastric juice is a thin, almost colorless fluid of acid reaction, and a specific gravity of 1003 to 1005. Free hydrochloric acid is produced to the amount of about 0.2 per cent to 0.3 per cent, to make the secretions and stomach contents acid. The smell of appetizing food will initiate the formation of this juice, which is increased in amount by the presence of food in the mouth. As the masticated and insalivated mass enters the stomach and is subjected to the action of the muscles, the maximum amount of secretion occurs. In twenty-four hours from 3 to 7 pints are made.

Gastric Digestion.—The food which enters the stomach is usually composed of various elements, as protein, carbohydrates, fats and cellulose.

By the action of the teeth and saliva in the mouth the food has been, more or less finely, divided and softened. It is alkaline in reaction and the starches have been more or less digested.

Mixing with the HCl in the stomach the reaction changes and the starch digestion ceases soon afterward.

Apparently, during gastric digestion the stomach divides into two parts. Between the cardiac orifice and that of the pylorus there is set up a series of circular muscular contractions that move

toward the pylorus in peristaltic waves. This produces a tube-like area, while the fundus remains more quiescent.

Consequently, the food in the fundus is not immediately acidulated and the digestion of the starches may continue for some time.

Meanwhile, a portion of the food is subjected to a series of squeezing movements, plus the chemical action of the gastric juice. These combined, change the food to a semi-fluid consistency, or to the so-called chyme. As this change occurs, the peristaltic waves of circular contractions throw the chyme against the pylorus, which opening, allows it to pass into the duodenum.

Compression of the fundus by the oblique and longitudinal muscle fibers carries another portion of food to be similarly treated, until the stomach is emptied.

This may require from two to five hours, according to the class to which the food belongs.

The pylorus seems to be incited to relax or open by the presence of free HCl in its vicinity. This prerequisite is met first by the carbohydrates. They absorb but little of the acid in the stomach, though stimulating the secretion of the gastric juice. Little being absorbed, the free acid has the chance to accumulate. The pylorus opens and the carbohydrates pass out early.

Proteins absorb much of the HCl, so it takes longer to accumulate a supply of free acid. Proteins usually require some two hours before passing out of the stomach.

Fats, other than that of milk, delay the secretion of gastric juice, with consequent very slow accumulation of free acid. They remain a long time in the stomach and pass out very slowly.

In the early part of digestion the gastric juice contains an excess of acid. This, causing the pylorus to open, is ejected into the duodenum, where it stimulates the formation of the alkaline bile and pancreatic juice. Reversal of the peristaltic wave carries this alkaline material back into the stomach, where it partly neutralizes the extreme acidity of the contents. By this means, the food sent later into the duodenum is not so irritating to its lining.

Of the enzymes in the gastric juice, *pepsin* converts some of the proteins into soluble peptones, that is, into material that will pass through the walls of capillaries and tissue cells. They can, therefore be absorbed from the digestive tract and into the cells.

Pepsin requires an acid medium in which to act. This condition being fulfilled by gastric juice, the protein is first made acid, or is changed into acid protein or syntonin, by hydrolysis.

Hydrolysis may be considered as the process, by which, in the presence of a ferment or enzyme, a substance takes up an atom of water, and then splits up into simpler compounds. Successive steps in the splitting may result in smaller molecules as well as simpler combinations, making the ensuing substance more easily soluble.

From syntonin, the supposed steps are to primary proteoses, to secondary proteoses, to peptones and possibly to amino-acids.

The protein and the resulting peptone are made up of amino-acids in varying number and arrangement, according to the kind of protein. Amino-acids are the units or building stones, out of which the protein molecule is constructed.

The second enzyme, *rennin*, coagulates the casein in milk, so it becomes insoluble. After this, the pepsin acts upon it to digest it.

The third enzyme, similar to one found in the pancreatic juice, is *lipase*, which digests the fat of milk.

These enzymes in the stomach do not, as a rule, completely digest the proteins, except the albuminoids, such as gelatin.

The envelope of fat cells is broken by the action of pepsin, and sets free the oil therein contained.

Vegetables having a cellulose framework are disintegrated in the stomach, though their protein is less easily acted upon than that of animals.

Chyme, as the material outgoing to the next laboratory is called, is of the consistency of pea soup, with minute particles of solid food suspended in a liquid.

The nerves by which these processes are controlled are partly autonomic, partly cerebrospinal.

The vagus causes tonicity of the muscles, in the absence of which no peristalsis occurs. The vasomotor impulses to the bloodvessels, determining the amount of blood supplied, come from the medulla oblongata *via* cells in the lateral horn of the spinal cord in the thoracic region and from the semilunar ganglion.

The secretory nerves of the epithelial cells originate in cells near the floor of the fourth ventricle. The sensory impressions that initiate and continue this activity come from the mucous membrane of the mouth, tongue and stomach and from the cerebral regions associated with the sight, odor and taste of food.

The plexi of Auerbach and Meissner supply nerves to the muscular coats of the stomach and, possibly, coördinate their activity.

The blood supply to the stomach is through the gastric artery with anastomosing branches from the hepatic and splenic.

The Small Intestine.—Leaving the stomach through the pyloric orifice, the chyme passes into the first part of the small intestine. For about 10 inches this is the *duodenum*. The rest of the small intestine makes up a total length of some 20 feet. This is divided into two parts, the *jejunum* and the *ileum*.

No distinct boundary separates these parts, but the first 8 feet is usually accepted as the jejunum.

The small intestine is a tube, averaging about $1\frac{1}{4}$ inches in diameter and laid in the middle of the abdomen in a series of apparently tangled loops. At its distal end it opens into the cæcum, the begin-

ning of the large intestine. It is held in place by the mesentery, or folds of peritoneum. (Fig. 285.)

Coats of the Small Intestine.—There are four layers in the walls of the small intestine, a serous, a muscular, a submucous and a mucous coat in the order named from without inward.

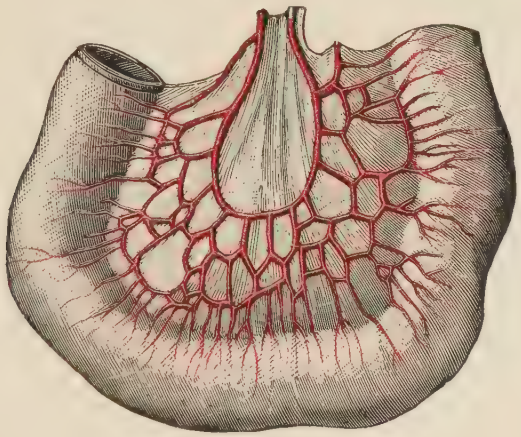


FIG. 285.—A loop of small intestine, showing the mode of distribution of the arteries. (Testut.)

The *serous* coat is the peritoneum. This starts from the anterior surface of the vertebral bodies as a sheet of tissue. It envelopes the tube and then goes back to the vertebral bodies. This anchors the coils firmly and forms a smooth, slippery covering for the intestine, so it may move freely, but be held in place.

The *muscular* coat is in two layers, one longitudinal and the other circular.

The *submucous* coat is of areolar tissue with a network of blood-vessels, nerves and lymphatics imbedded in it.

The *mucous* coat on the inner surface presents a velvety appearance and many ridges. The ridges are the *valvulæ conniventes*, which increase the working surface of the tube and hold the food in contact with the digestive juices for a longer period.

Villi.—The velvety appearance is due to some 4,000,000 to 10,000,000 villi. These are organs of absorption. They are less than $\frac{1}{25}$ of an inch in height and $\frac{1}{70}$ of an inch in diameter. (Fig. 286.)

The villi are conical or cylindrical in shape with a lymph radicle in the middle. (These are special lymph vessels called lacteals). Around the lacteal is a network of capillaries, some unstriated muscle fibers and a mass of nucleated cells. The whole is covered by columnar epithelium. (Fig. 287.)

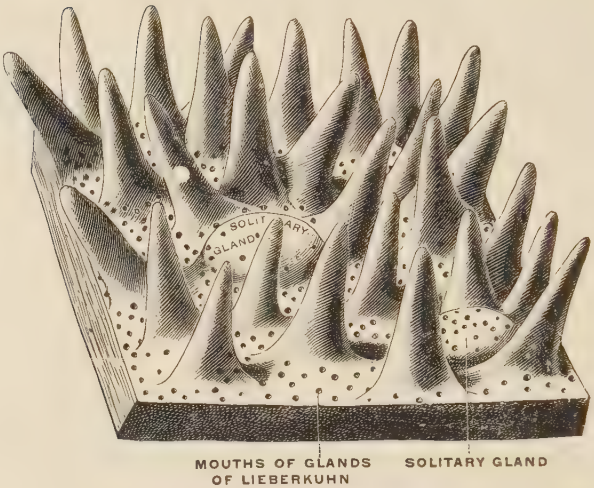


FIG. 286.—Free surface of the mucous membrane of the small intestine, showing villi, solitary glands and openings of the intestinal glands. Semidiagrammatic. (Testut.)

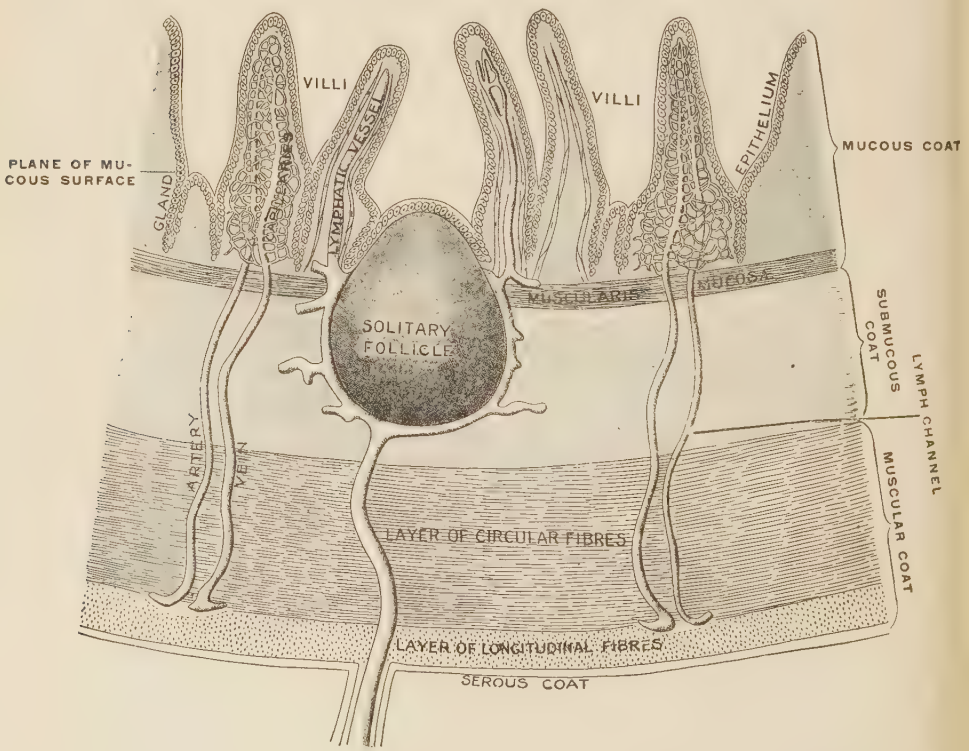


FIG. 287.—Mucosa of small intestine in ideal vertical cross-section. (Testut, after Heitzmann.)

Crypts of Lieberkühn.—In the mucous membrane are many tubular glands (crypts of Lieberkühn) which secrete the *succus entericus* or intestinal juice and mucus.

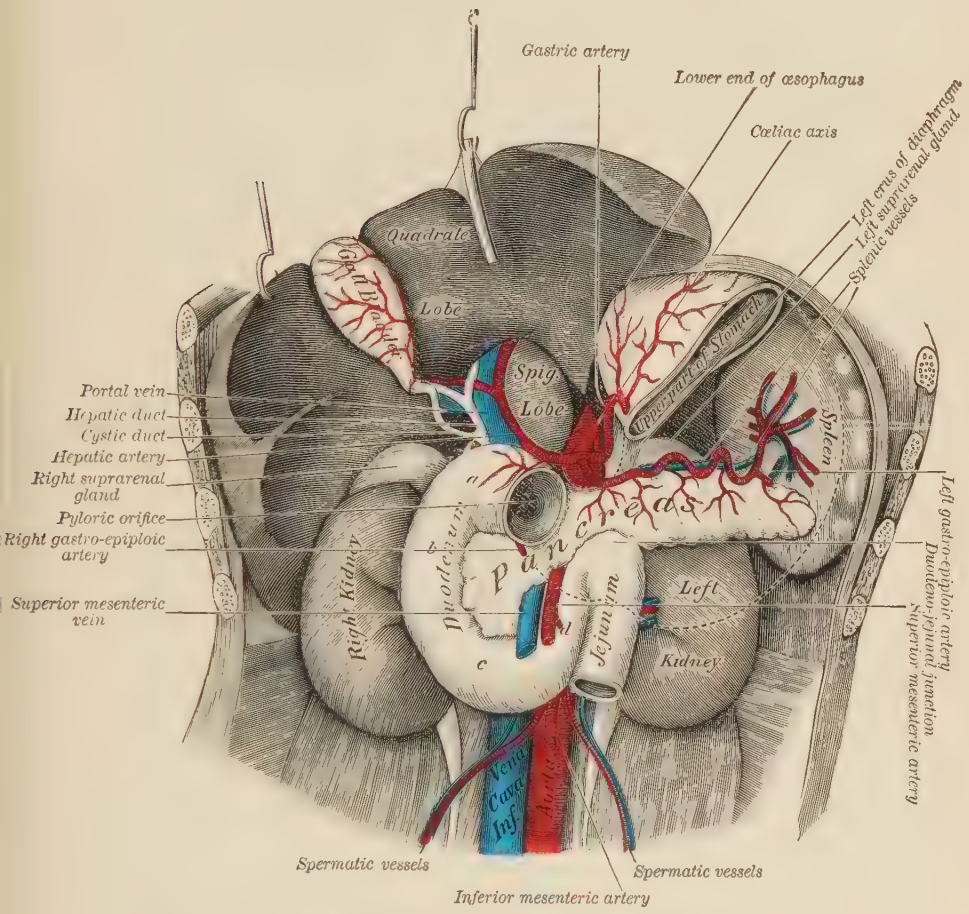


FIG. 288.—The duodenum, its four parts marked *a*, *b*, *c*, *d*. The liver is lifted up; the greater part of the stomach is removed, broken lines indicating its former position. (Testut.)

Lymph Nodules.—In the walls of the intestine are small bodies that are similar to lymph nodes. These are *solitary glands*, and their work is related to that of the nodes in the mesentery. (Fig. 287.)

The Duodenum.—The duodenum winds around the head of the pancreas (Fig. 288), and receives a secretion from that organ, from

the liver and from its own peculiar glands (Brunner's glands) (Fig. 289.)

The 10 inches of small intestine called the duodenum is responsible for a large part of the work of digestion.

Suppose an ordinary dinner to be eaten. This would represent a combination of water, meat, bread, butter, vegetables (either the green leafy kind, the starchy or those containing protein) mineral salts and some sweet or fruit. All the classes of food will be represented.

The carbohydrates have had some digestion in the mouth, so that after passing through the stomach, in the chyme they will be represented by maltose and dextrin.

The proteins, either partly or wholly digested in the stomach, in the chyme appear as acid protein, proteoses and peptones.

FIG. 289.—Duodenal gland. (Frey.)

The fats, with their envelopes digested in the stomach, appear in the chyme as oil globules, more or less fine. The cane, malt and milk sugars have not been changed. The mineral salts, indigestible parts of the food, as cellulose, etc., and water are included in the acid mixture which passes from the stomach into the duodenum.

As this material is received, the formation of the alkaline pancreatic and intestinal juices, and the bile is stimulated. These, mixed with the chyme, neutralize it, more or less completely, so providing a medium in which the intestinal enzymes can act. Gastric digestion stops, and the intestinal or final digestive steps are inaugurated.

Intestinal Digestion. The enzymes in the pancreatic and intestinal juices may be said to combine those of the mouth and stomach, while requiring an alkaline or neutral medium in which to act.

Amylose or amylopsin is an agent in starch conversion that is more energetic than ptyalin.

Trypsin acts upon proteins, carrying their cleavage a step further than does pepsin, *i. e.*, the peptones are split up into the amino-acids or the final nitrogen-holding simplest compounds.

Still another enzyme in the pancreatic juice and in the intestinal juice which apparently acts in the same way is *erepsin.*

Steapsin or *lipase* changes the fats into acid bodies (stearic, palmitic and oleic acids) and glycerin. As HCl is formed in the stomach, another chemical, this time an alkali, the carbonate of potash or soda is formed in the intestine. This unites with the fatty acids and forms a soap. The rest of the oils divide into minute globules which are suspended in the liquid soap as an emulsion. This conversion of fat into an emulsion is facilitated by the *bile* which increases the activity of the lipase.

The intestinal juice, derived from Brunner's glands, and those of Lieberkühn contains several enzymes, given below.

Erepsin is supposed to complete the conversion of protein into the amino-acids which can be absorbed directly into the blood stream and into the tissue cells, where they may be rebuilt into protein.

Invertase or *saccharose* will change cane sugar to dextrose and levulose.

Maltase changes malt sugar or maltose to dextrose. The salivary digestion has converted starch into maltose, so here the change makes it capable of absorption.

Milk sugar or lactose is converted into dextrose and galactose by *lactase.*

These are the principal compound sugars that are ingested, which must be made absorbable and assimilable by the intestinal secretion.

The *bile* from the liver is of a dark greenish-red color, bitter in taste and odorless. It helps in the emulsification of fats, promotes intestinal peristalsis, inhibits putrefaction in the intestinal tract and promotes the absorption of fats.

Movements of the Intestine.—The movements of the intestine consists of a series of contractions by the circular muscle fibers. A section of the tube undergoes contraction by which the contained food is squeezed and brought into contact with the digestive juice. This contraction is in the form of a series of rings, which presently are changed in location, so the spaces between the rings become constricted. This continues for a time, and then by the peristaltic wave the food is moved along to another place in the tube, where the process is repeated. This is called by Cannon *rhythmic segmentation.* (Fig. 290.)

As the digestion proceeds, and the food passes along the intestine, those elements that have been sufficiently acted upon are picked up by the epithelial cells that cover the villi.

The carbohydrates and protein pass from the cells into the

capillaries of the intestinal loops, while the fats go from the cells into the lymphatics in the villi. These lymph vessels, called lacteals, unite and empty into the *receptaculum chyli*, from whence the *chyle* (as the digested fat is called) passes through the *thoracic duct* into the subclavian vein.

The digested carbohydrates and protein are taken by the capillaries into the venous radicles of the superior mesenteric vein, and thence into the portal vein, on the way to the liver. (See Portal Circulation, page 280.)

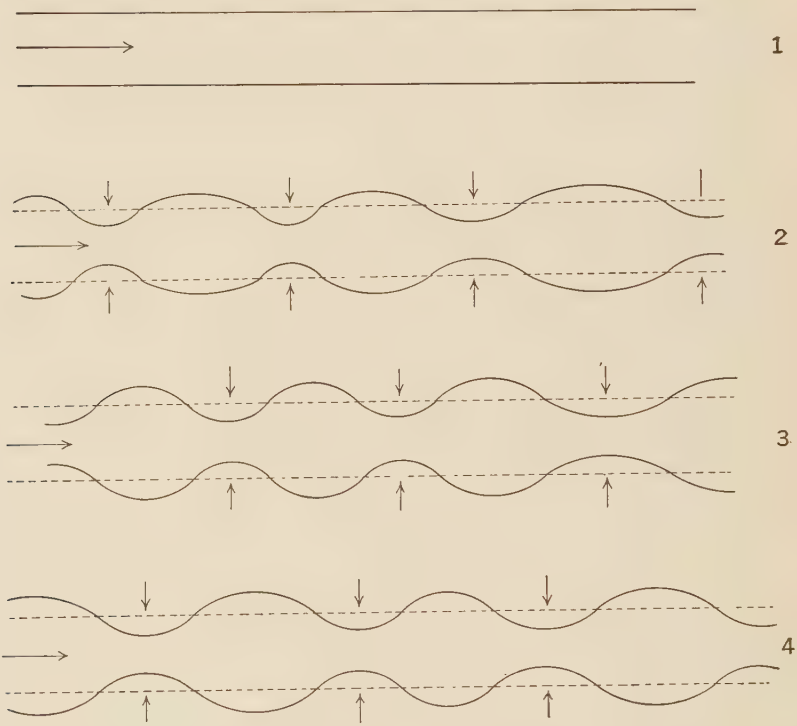


FIG. 290.—Rhythmic segmentation (adapted from Cannon). 1, a segment of the small intestine; 2, same segment with four constrictions, due to contraction of circular fibers; 3, four new areas of constriction at midway of former action; 4, same as 2.

ACCESSORY ORGANS TO THE DIGESTIVE TRACT.

There are two organs in the abdomen that are accessory to the alimentary tract, the *liver* and the *pancreas*.

The Liver.—The liver is in the upper right quadrant of the abdomen, extending to the left beyond the middle line. It is the largest gland in the body, weighing between 3 and $3\frac{1}{2}$ pounds. It is wedge-shaped with the greatest width 8 to 9 inches, its height 6 to

7 inches, and its antero-posterior diameter 4 to 5 inches. The base of the wedge is to the right. It is of soft solid consistency, friable and a dark reddish-brown in color.

The liver is divided by five fissures into five lobes. The left and right lobes are primary divisions, but the right lobe is subdivided into the quadratus, spigelii, and caudatus. The fissures give passage to blood-vessels and one of them is the bed of the gall-bladder. (Fig. 291.)

The liver is attached to the under surface of the diaphragm, and to the anterior wall of the abdomen by folds of peritoneum. It is covered with a fibrous membrane, which forms a capsule. The substance of the liver is made up of small units of structure called *lobules*. These are held together by areolar tissue and by the ramifications of the portal vein, hepatic artery, hepatic vein, bile ducts, lymphatics and nerves.

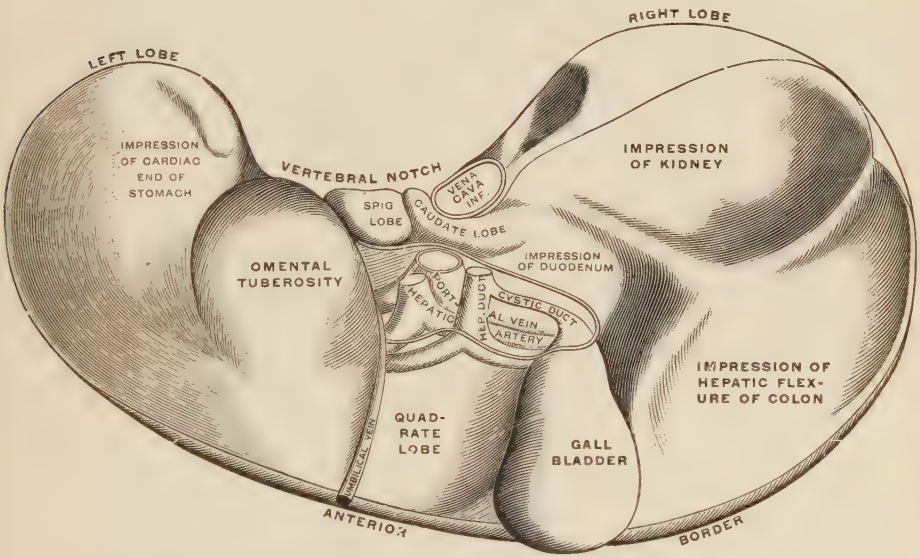


FIG. 291.—The liver, lower surface. (Drawn from the His cast.) (Gerrish.)

The Lobule.—This is the working part of the liver, the laboratory in which the numerous functions of the liver take place. They are small granular bodies about $\frac{1}{20}$ to $\frac{1}{10}$ of an inch in diameter, with irregular outlines. The lobules have in the center a small vein which issues from it, carrying the collected blood from the portal vein capillaries and those of the hepatic artery. Around this vein the hepatic cells are grouped in radiating columns, as closely packed as possible, leaving room only for the capillaries of the portal veins, the bile ducts and nerves on the sides. The cells are abundantly supplied by the portal vein with material which includes newly

digested food. From this, bile is manufactured and given off to the small ducts on the sides of the cells.

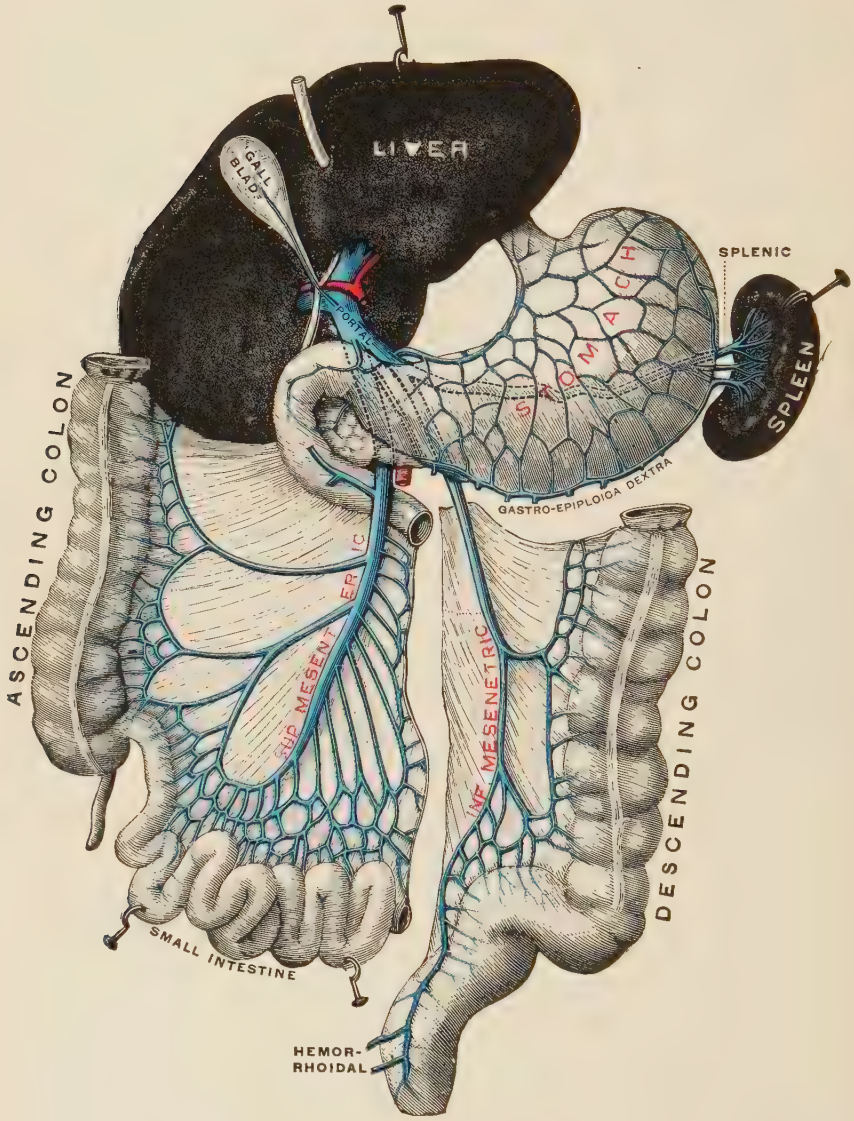


FIG. 292.—Portal system of veins. The liver is turned upward and backward, and the transverse colon and most of the small intestines are removed. (Testut.)

Blood also comes to the lobule by way of the capillaries of the hepatic artery. This supply is mainly concerned with the nutrition

of the lobule itself. The venous capillaries which arise after the lobule is supplied, carry off by way of the hepatic vein to the vena cava, the blood which has come in through the portal vein. Besides making bile, the liver cells work over the nitrogenous waste of the blood into a new substance called *urea*. This is really an internal secretion of the cells, as it does not pass off through ducts as the bile does, but goes back into the blood. Still a third function of the liver cell is the storage of glycogen. Glycogen, a form of starch, is formed from the dextrose in the blood of the portal vein. It is stored in the liver cells, and when the muscle cells need fuel a portion of glycogen is reconverted to dextrose to pass to the muscle *via* the blood stream. The need for fuel is more or less constant, but the digestive process is intermittent. Hence, the necessity for a storehouse from which a supply may be doled out for the hourly need.

It is evident that dextrose, itself, being absorbable, could not be stored, so the two changes must be made, in which sugar is changed back to starch, stored and later, again converted into dextrose.

The liver cells are the storehouses, with a supply ready to be taken up by the blood and carried to the parts where it is used. Glycogen could also be considered as an internal secretion, since it passes back into the blood instead of into a duct.

A fourth function is the conversion of the products of the putrefaction of proteins in the large intestines, as indol, skatol, phenol, etc., into compounds that are afterward excreted by the kidneys.

Gall-bladder.—In the process of digestion, bile is used, being poured out in the duodenum on the entrance of the food of an acid reaction from the stomach. The bile so used has been stored in the gall-bladder, following its previous formation. The small ducts of the right lobe unite into a large duct; those of the left lobe do the same, and the two ducts form one large vessel, the *hepatic duct*. The cystic duct expands its free end as the gall-bladder. Here the bile is stored until needed, when it passes down out of the bladder through the *cystic duct*. The cystic duct unites with the hepatic duct to form the "ductus communis choledochus," or common bile duct. This opens into the duodenum about 4 inches beyond the pyloric end of the stomach.

The gall-bladder is about 4 inches long, pear-shaped, and holds about 1 ounce. It is on the under surface of the front edge of the liver. (Fig. 293.)

The Pancreas.—This is a large gland in the upper part of the abdomen, behind the stomach. It is somewhat hammer-shaped, with the head embraced by the duodenum. It is about 6 inches long, $1\frac{1}{2}$ inches wide and from $\frac{1}{2}$ to 1 inch thick. (Fig. 294.)

It is pinkish in color and weighs between 2 and 3 ounces. The structure of the pancreas is that of a compound tubular gland.

The tubes are coiled in small masses called lobules, with the cells short and conical. (Fig. 295.)

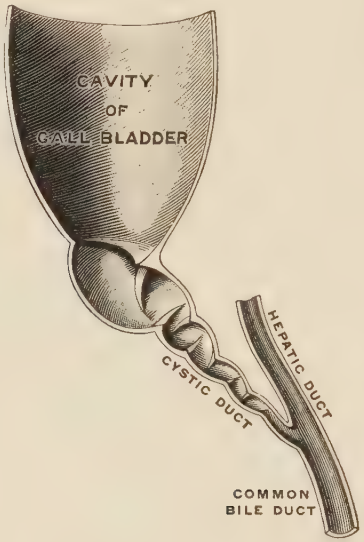


FIG. 293.—The cystic duct in section, with part of the gall-bladder, hepatic and common bile ducts. (Testut.)

FIG. 294.—The pancreas, dorsal view. The head is seen in the embrace of the duodenum. The portal vein and superior mesenteric artery lie behind the neck. (Drawn from the His cast.) (Gerrish.)

In its work the gland is similar to the salivary glands, secreting pancreatic juice which passes out through the duct of Santorini into the duodenum (Fig. 296).

This gland has other cells than those concerned in the production of pancreatic juice. The so-called "islands of Langerhans" have to do with forming an internal secretion which profoundly influences

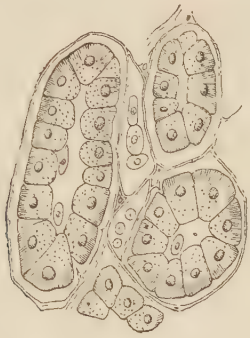


FIG. 295.—Cross-section of pancreatic acini. (Testut.)

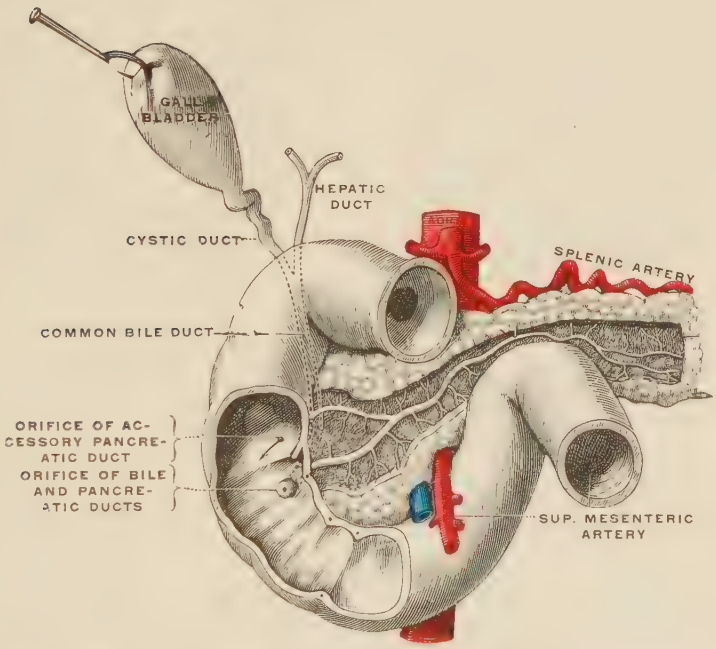


FIG. 296.—Ducts of the pancreas. Part of the front wall of the duodenum is cut away. (Testut.)

nutrition. Death from inanition in two or three weeks follows the removal of the pancreas. The failure of its internal secretion "insulin," affects the digestion of sugars, so they are retained in the blood and the condition of glycosuria results.

Absorption.—The combination of forces acting on the food in the intestine, chemical, thermal and mechanical, reduce it to a condition in which it will pass through the walls of the capillaries and the lymph radicles into the general circulation. Throughout the 20 feet of small intestine this absorption takes place until the material reaches the beginning of the large intestine. Little then remains except the waste of the food, that is, the parts of the food that cannot yield nourishment, and water. This arrives at the beginning of the large intestine about twelve hours after it was first ingested.

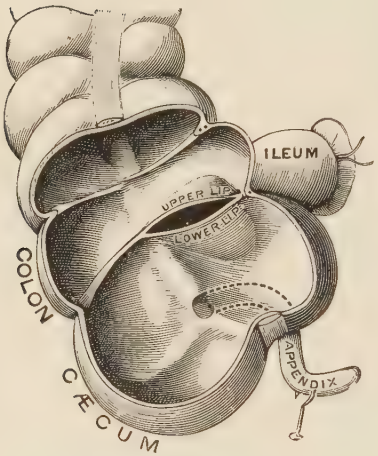


FIG. 297.—Cavity of the cæcum, its front wall having been cut away. The ileocæcal valve and the opening of the appendix are shown. (Testut.)

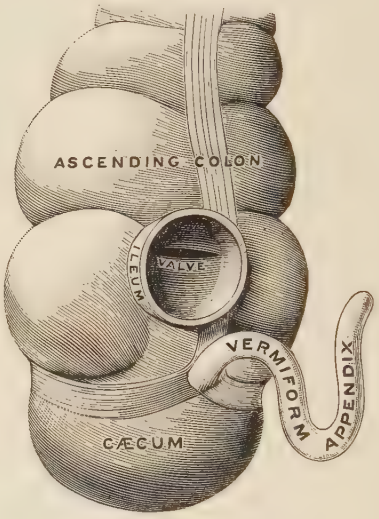


FIG. 298.—The cæcum, dorso-mesia view, showing the ileum-side of the ileocæcal valve, and the beginning of the three muscular ribbons. (Testut.)

The Large Intestine.—At the termination of the ileum the small intestine opens into the large intestine at the *ileo-cecal* valve. This is a fold of mucous membrane at the opening in the cecum, which prevents regurgitation. The large intestine is about 5 feet long and 4 inches in diameter. It is divided into the *cecum*, the *colon* (ascending, transverse, descending and sigmoid flexure) and the *rectum*.

The cecum is a blind pouch at the beginning of the colon, in the lower right side of the abdomen. From it a small tube, called the *vermiform appendix* passes downward and backward. (Figs. 297 and 298.)

Leading from the cecum is the colon in four parts. The ascending colon passes up on the right side of the abdomen as high as the liver. There it turns (hepatic flexure) and crosses the abdomen

at the level of the anterior-superior spine of the ilium, as the transverse colon.

On the left side it turns (splenic flexure) and as the *descending colon*, passes downward to about the level of the pelvic brim. Here it makes an "S"-shaped turn, becoming the *sigmoid flexure*.

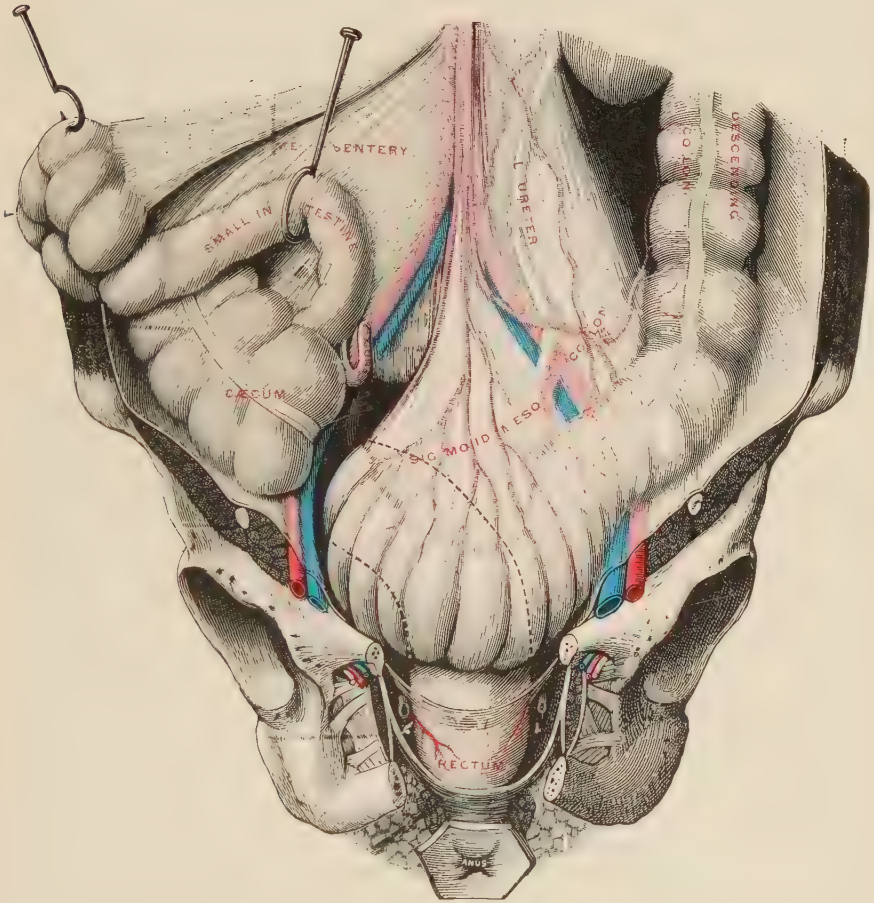


FIG. 299.—Sigmoid colon and rectum, front view. The broken lines indicate the situation of the concealed part of the sigmoid colon. The small intestine is drawn away, and the anus is turned forward. (Testut.)

In the back of the pelvis this becomes the *rectum*, which terminates at the surface middle line as an opening, the *anus*.

The large intestine has three coats. The outer, peritoneal, is the extension of the peritoneum.

The middle coat consists of two layers of plain muscle fibers, an

inner circular layer and the outer longitudinal layer. The latter fibers are placed in three bands, and being shorter than the tube, puckers it, forming saccules which serve to hold the contents for a longer period.

The inner coat is mucous, containing neither villi nor valvulæ conniventes. It does have many mucous follicles, the cells of which secrete a large amount of mucus.

The material brought to the large intestine is liquid, containing water, the undigested remnants of the food, mineral matters, parts of the bile, and these mix with the mucus from the inner lining of the tube. These form the *feces.*

The Feces.—These are carried along by the peristaltic action as far as the middle of the transverse colon. Then a reverse peristaltic wave carries them back toward the cecum. This back-and-forth movement effects a more thorough mixture of the contents, and provides a longer time for the absorption of the water. By this absorption the feces become of a soft solid consistency, varying in color from light yellow to black, according to the character of the food and the length of time they remain in the tube.

As the feces are subjected to the peristaltic movements of the intestines, they pass on through the transverse and descending colon, finally being stored in the sigmoid flexure. Here they remain until their presence initiates a desire for *defecation,* or their expulsion, when they pass into the rectum and then out of the body. This is effected by the peristaltic action of the intestine, aided by the compression provided by the contraction of the diaphragm and the muscles of the abdominal wall.

The *rectum* is not a reservoir for the feces, but simply a passage way. An internal sphincter, an inch above the anus, is surrounded by involuntary muscle fibers, and remains closed, preventing the escape of feces until they enter the rectum. At the anus an external ring of sphincter muscles is under the control of the will.

Intestinal Fermentation.—When food in excessive quantity has been taken or the digestive enzymes are defective, their stay in the intestine is prolonged, resulting through the action of the many bacteria which are found here, in fermentation.

The "intestinal flora," so-called, comprise bacteria that promote either fermentation or putrefaction. It is supposed that animal food elements undergo putrefactive changes, while vegetable products undergo those of fermentation. Hence, an excessive meat diet causes very offensive smelling feces. Among the numerous products of these changes are *indol,* an antecedent of indican, and *skatol,* which gives the odor to the feces. These are carried in the portal vein to the liver, and later are excreted by the kidneys.

Gases are also produced, such as sulphuretted hydrogen.

About twelve or thirteen hours are needed for the passage of

the feces through the large intestine, so in about twenty-four hours after food is eaten the waste is ready to be expelled from the body.

Blood Supply of the Intestines.—The small intestine receives its blood supply from the *superior mesenteric* artery, with anastomosing branches from most of the divisions of the abdominal aorta. In a like manner the main supply of the large intestine is from the *inferior mesenteric*. The branches usually run in the mesentery that supports the coils of intestines, and then subdivide in the submucous coat.

Nerve Supply to the Intestines.—For the activity of these organs the vasomotor nerves regulate the amount of blood supplied. Secretory impulses come through the vagus from centers in the medulla to the cells. The activity seems to be initiated by sensory messages from the intestinal walls, which are produced by the presence of food.

There are sensory nerves associated with the organs in the thoracic and abdominal cavities. When the function of these organs is normally performed, no sensations of which we are conscious arise from them. But, in abnormal or pathological conditions, decided sensations of pain compel attention. In this way Nature gives warning of the necessity for a rest of the part.

However, these sensory impressions, while not affecting consciousness, initiate reflex activity.

Sensory fibers arise in cells of the ganglia of the dorsal nerve roots in the thoracic and lumbar nerves. These fibers go in the white rami communicantes to nerve centers, which transfer the stimuli to nerve trunks that go to the various organs. The cardiac plexus carries these fibers to the heart; the splanchnic nerves to the abdominal viscera; the sacral nerves to the pelvic viscera.

When food materials, having undergone "rhythmic segmentation," send afferent messages as to its condition the initiation of the peristaltic wave follows, as a reflex action.

Afferent fibers, then, carry impulses to centers in the spinal cord and arborize around the cells of the center. From these cells efferent axons pass out to the sympathetic ganglion (semilunar) as preganglionic fibers and arborize around cells in the ganglion. From their ganglion cells other axons, gray postganglionic fibers pass to the plain muscle fibers in the intestinal walls. Or, they may in a similar way go to the glandular cells.

The "rhythmic segmentation," so-named by Cannon, appears to be initiated by the pressure of food on the intestinal walls, and to be carried on through their own power, by the muscle cells without the mediation of the plexi in the walls, or of the ganglia of the sympathetic.

The activity of the large intestine is due to impulses of similar kind from the lower lumbar and sacral nerves.

QUESTIONS.

What relation exists between the composition of the body and the composition of the common foods?

Name the processes in converting food into a part of the body in the order of occurrence.

What chemical agents are involved in digestion?

What mechanical agents are involved in digestion?

Name the enzymes acting on food in the stomach, in the mouth, in the intestine.

What are the uses of teeth?

Name and locate the salivary glands.

What are the functions of the tonsils?

What are the successive steps in the digestion of proteins?

What is glycogen? Where does it originate?

Describe "villi." Of what use are they?

What are "lacteals"?

Describe a lobule of the liver.

What secretion is produced in the "islands of Langerhans"? Its use?

What are the parts of the large intestine, and their uses?

CHAPTER XII.

DIETETICS, NUTRITION AND ANIMAL HEAT.

CLASSES OF FOOD AND HOW DIGESTED.

Having considered the apparatus by which food is digested it remains to describe the kinds of food according to their chemical composition.

Very few foods are purely and strictly in one class, but most of them are a combination of carbohydrates, protein and fats, in varying proportions.

A glance at the table following will show the percentages of the three classes in some of the commoner articles of diet. The meats have much water, considerable protein, some fat, but little carbohydrate. They are classed as protein food. Certain vegetables as beans and peas contain little water, as much protein as meat and considerable starch. They are the vegetable proteins.

Proteins are either animal or vegetable and are found in many forms. Among them are casein in milk and cheese; albumen in the white of egg; vitellin in the yolk of egg; myosin and syntonin in meat; gluten in flour; legumen in peas and beans, and the protein in nuts.

Proteins are used in the body for repairing and building-up the cells, as they are stable in their composition. They are the only foods that may be said to be absolutely essential to life, as no repair can take place without them. They may serve as fuel, though they are rather expensive for that purpose, and in addition, put too much strain upon the excretory organs.

Among the common foods that are predominantly protein are: Lean meat, milk, eggs, cheese, fish, wheat, oatmeal, peas, beans and peanuts. The animal proteins are more easily digested than those derived from vegetable sources, and contain less waste.

The digestion of proteins occurs in the stomach and the small intestine in the presence of the proteolytic enzymes, pepsin, rennin, trypsin and erepsin.

The various so-called carbohydrate foods contain small quantities of protein in many cases, but are mainly starches and sugars. The starches are found in cereals, potatoes, some fruits and legumes. The sugars include cane sugar, maple, beet, grape, malt and milk sugars as well as that found in meat.

AVERAGE CHEMICAL COMPOSITION OF FOODS.[1]

Food materials.	Water, per cent.	Protein, per cent.	Fat, per cent.	Carbohydrates, per cent.	Ash, per cent.	Fuel value calories, per pound.
Beef:						
Sirloin steak	61.9	18.9	18.5	.....	1.0	1130
Round steak	67.8	20.9	18.6	.....	1.1	835
Veal, leg	71.7	20.7	6.7	.....	1.1	670
Lamb, leg	58.6	18.6	22.6	.....	1.9	1300
Chops broiled	47.6	21.7	29.9	.....	1.3	1665
Mutton:						
Roast leg	50.9	25.9	22.6	.....	1.2	1420
Pork, loin	66.5	18.9	13.0	.....	1.0	900
Smoked ham	39.8	16.5	38.8	.....	4.7	1945
Chicken	70.3	21.9	7.4	.....	1.1	835
Fish:						
Cod	82.6	16.5	0.4	1.2	...	325
Salmon	64.6	22.0	12.8	1.4	...	950
Eggs	73.7	13.4	10.5	.....	1.0	720
Butter	11.0	1.0	85.0	.....	3.0	3605
Buttermilk	91.0	3.0	0.5	4.8	0.7	165
Cheese:						
American	31.6	28.8	35.9	.....	3.5	2055
Full cream	34.2	25.9	33.7	2.4	3.8	1959
Cream	74.0	2.5	18.5	4.5	0.5	910
Whole milk	87.0	3.3	4.0	5.0	0.7	325
Skimmed milk	90.5	3.4	0.3	5.1	0.7	170
Cracked wheat	10.1	11.1	1.7	75.5	1.6	1685
Macaroni	10.3	13.4	0.9	74.1	1.3	1665
Oatmeal	7.3	16.1	7.2	67.5	1.9	1860
Rice	12.3	8.0	0.3	79.0	0.4	1630
Flour:						
Fine white	13.8	7.9	1.4	76.0	0.5	1625
Entire wheat	11.4	13.8	1.9	71.9	1.0	1675
Bread:						
White	35.3	9.2	1.3	53.1	1.1	1215
Entire wheat	38.4	9.7	0.9	40.7	1.3	1140
Sugar, fine white	....	....	....	100.0	...	1860
Vegetables:						
Green butter beans	58.9	9.4	0.6	29.1	2.0	740
Fresh carrots	88.2	1.1	0.4	9.3	1.0	210
Green corn	75.4	0.8	1.1	19.7	0.7	470
Green peas	74.6	7.0	0.5	16.9	1.0	465
Boiled potatoes	75.5	2.5	0.1	18.4	1.0	385
Fruits:						
Apples	84.6	0.4	0.5	14.2	0.3	290
Bananas	75.3	1.3	0.6	22.0	0.8	460
Grapes	58.0	1.0	1.2	14.4	0.4	335
Nuts:						
Almonds	4.8	21.0	54.9	17.3	2.0	3030
Chestnuts	45.0	6.2	5.4	42.1	1.3	1125
Peanuts	9.2	25.8	38.6	24.4	2.0	2560
Walnuts	2.5	18.4	64.4	13.0	1.7	3300
Chocolate	5.9	12.9	48.7	30.3	2.2	2860
Cocoa	4.6	21.6	18.9	37.7	7.2	2320

[1] Abstracted from "Food Values," by Edwin A. Locke.

Carbohydrates are the least expensive of the various kinds of food and constitute the larger bulk of articles eaten. They are easily oxidized and converted into heat and muscle energy, and into fatty tissue, when taken in excess of the body needs. The digestion of starches occurs in the mouth and small intestine in the presence of the amylolytic enzymes, ptyalin, amylase and pancreatic diastase.

The digestion of sugars occurs in the small intestine, in the presence of the sugar-splitting enzymes.

Carbohydrates enter the blood as dextrose. Its oxidation results in the production of heat, kinetic energy, H_2O and CO_2.

Fats are either animal or vegetable. The principal forms, according to their firmness are stearin, palmatin, margarin and olein. They are found in most of the animal foods, in the dairy products and in nuts. Various vegetable oils are derived from the seeds of cotton, from corn, etc. Fats form a powerful fuel food, giving heat and energy, but are rather difficult to digest and oxidize. The outside envelope of fats is removed in the stomach by the gastric juice, but their digestion takes place in the small intestine by means of bile and steapsin.

REQUISITES OF A DIET.

It is important to consider what quantity and proportion of the various classes of food are essential to health. In the study of this problem, stated portions of the three principal food elements were burned to determine their value as fuel. The unit of measurement is the *calorie*, that is, the amount of heat necessary to raise 1 kilogram of water 1° C. in temperature. This investigation fixed the fuel value of carbohydrates and proteins at 4.1 calories per gram, and that of fat at 9.3 calories per gram.

The analysis of the excreta, the products of perspiration and respiration, shows the amount of carbon and nitrogen, plus the water that is excreted in a given time. This shows the amount of tissue that has broken down by oxidation. As the proportion of the elements in food products is known, it is evident how much food has been consumed and how much must be taken to replace it.

Various investigators have examined these relations, and arrived at various results. The principal variant is as to the amount of nitrogen needed to maintain *nitrogen equilibrium*. By this is meant that the intake of nitrogen equals the outgo. This seems to vary according to the amount ingested. If much nitrogen is taken in much is eliminated. If little nitrogen is taken in, little is eliminated, so that apparently, nitrogenous equilibrium may be maintained with different amounts of nitrogen food. The quantity estimated for an average man doing a moderate amount of work, runs from 60 to 120 gm. of protein a day. With the maximum of 120 gm., go

90 gm. of fat, and 320 gm. of carbohydrates. A rough estimate for the proportionate amounts of food would be 1 part of protein for every 4 parts of fats and carbohydrates combined. A fairly generous protein intake seems to exert a stimulating effect upon metabolism in general.

In estimating the amount of food needed it is customary to allow 40 calories of food for each kilogram of weight in men, and 30 calories for women. A man weighing 180 pounds would have 3200 calories a day, and a woman of 120 pounds would have 1600 calories by this estimate. This assumes much less muscular activity for women than for men. Besides the elements of water, O,CHON,CH_2O, fats and salts, required by the body certain materials called "vitamins" are needed. Little is known of these, but it is definitely established that they must be supplied to the body or inanition results.

Vitamins.—Five different kinds of vitamins have been recognized:

Vitamin A, or "fat-soluble A," is associated with and soluble in the fat of milk, cod-liver oil, eggs, etc. This appears to be essential to growth, as animals fed on a diet devoid of vitamin A soon cease growing, lose weight and become susceptible to respiratory diseases and inflammation of the eyes. Some of the foods that contain "A" are green vegetables, sweet potatoes, butter (*not* lard), tomatoes, alfalfa and clover. Vitamin A is not abundant in cereals. Butter from cows fed on green food contains more of this vitamin than that from stall-fed cows.

Vitamin B, or "water-soluble B," is present in the husk and germ of wheat, rice, corn, beans, etc. It is abundant in green plant foods, carrots, parsnips, citrus fruits, etc. It is absent in polished rice and other highly *refined* food. Deprivation of "B" results in "beri-beri," or neuritis. Those who eat a variety of fresh foods do not have such troubles.

Vitamin C.—This is "water-soluble C," the antiscorbutic vitamin. It is present in the juices of fresh fruits and vegetables. It is destroyed in milk by sterilization. Meats are poor in "C." Scurvy is produced in those deprived of "C" for any length of time.

Vitamin D.—This is fat-soluble, and seems to be concerned in the proper balance of lime and phosphorus in the blood. It is plentiful in cod-liver oil. It is not in spinach and lettuce. Some foods that have "A" soluble do not contain "D" soluble. It is more stable than the other vitamins, and not easily destroyed by ordinary cooking. Mineral acids and prolonged high temperatures will destroy it.

The ultraviolet rays are said to develop this vitamin in vegetables and in oils which are deficient in it.

Vitamin E or X.—This is claimed to be necessary in the food of an expectant mother to properly develop the child, and provide its

natural breast food. It is found in the wheat germ, green food, olive and cotton-seed oil.

Vitamins are produced by plants; animals may store them in the heart, liver and kidneys.

It is thought that vitamins may initiate or accelerate some reactions that could not occur without their presence.

Roughage.—For normal movements of the bowels a certain amount of "roughage" is necessary. This is mainly "cellulose," the indigestible framework of fruits and vegetables, as well as the outer husk of grains. It adds bulk to the mass in the intestine, and so stimulates its activity.

METABOLISM.

The body uses food to maintain itself in existence and to develop the various forms of energy, as heat, movement, thought and secretion. The process by which the food elements in the blood become available for these purposes is called *metabolism.*

This may be considered as a series of chemical reactions by which the potential energy of the food is converted into the kinetic or actual energy of the body, and also the process of building relatively simple materials into the complex constituents of the cells—the development of new materials therein and the breaking down of complex substances into simpler ones which are subsequently eliminated as waste.

This divides metabolism into that of the cell (tissue metabolism) and that of the food materials (food metabolism) which takes place in the lymph spaces around the cells.

In the cells the building-up process is called *anabolism.* The breaking-down in *katabolism.*

Ordinarily in health, the greater part of the metabolic activity is that of the food. Variations of this are due to the quantity and kind of food taken, the amount of exercise, physical and mental, and the position of the body.

The metabolic process is comparable to the combustion of fuel under a boiler. Chemical changes, chiefly oxidative, occur with the development of heat, light, motion or electricity.

When anabolism and katabolism are equal the body is in a condition of nutritive equilibrium, or it remains of the same weight, size and strength. When anabolism exceeds katabolism, as it should do during the years of the body's growth, the weight, size and strength increase. When katabolism exceeds anabolism, as in starvation, the three above elements diminish. The organism calls upon the stored glycogen in the liver, upon the fats and finally upon the built-up proteins for use in maintaining the body heat.

As metabolism develops energy, and energy is manifested as heat, movement, thought and secretion, if the latter three are

checked, apparently heat only is produced. That is, in the resting condition, when neither movement, thought or secretion is necessary, heat must be produced to maintain the temperature of the body.

It is found possible to accurately measure this heat production. The caloric equivalents of the various food elements being known, the amount of fuel used can be estimated from the amount of heat produced.

The machine used for measuring the heat produced is a "respiration calorimeter," in which the heat from the body warms a given amount of water to a certain degree. These machines are complicated and expensive, requiring highly skilled expert manipulation. A modified apparatus is, therefore, more generally used, depending upon the heat equivalent of a definite amount of oxygen which may be consumed in a given time in respiration.

The activity of metabolism in health varies according to the muscular or mental activity, the position of the body, the time of day, the amount of food taken and the temperature. In pathological conditions there is much more variation, due to the presence or absence of more or less of the secretions of the ductless glands.

Basal Metabolism.—The measurement of tissue metabolism is usually made about 7 or 8 A.M. on an empty stomach, in the recumbent position and with the room temperature about 70° F.

This early hour gives the amount of tissue metabolism because no new food products are in the blood (since thirteen or fourteen hours have elapsed since the last meal), the waste products have mostly been carried away and following the night's rest the metabolic processes are at their lowest ebb. The term *basal metabolism* denotes this minimal condition. It is a fairly accurate measurement of the chemical changes taking place in the body cells.

Protein Metabolism.—The food materials are metabolized in somewhat different ways, according to their chemical composition. In the digestive process proteins are transformed into amino-acids. Part of these go into the large intestine, are subjected to bacterial putrefaction and break down into simpler compounds as indol, phenol and skatol. Some of these pass off in the feces—some are absorbed and go to the liver where they are worked over into urea.

A part of the amino-acids pass directly into the portal vein, thence into the liver, some being converted into urea.

A part of the amino-acids pass directly into the blood and are taken into the tissue cells and built up into its framework. The amount so used varies. In immature animals a greater amount than in mature ones, is so used.

Some of these elements not needed by the cells are available for heat production by being metabolized outside the cells. To them the name "circulating proteins" is sometimes applied. They split

up, forming carbonate of ammonia which enters into urea, and a compound of C, H and O, which is converted into CO_2 and H_2O with the development of heat.

The nuclei of meat cells taken as food undergo a breaking-up into guanin and adenin which subsequently gives rise to uric acid.

Fat Metabolism.—If a proper amount of fat is taken daily it is quickly transformed in the tissue spaces into its ultimate elements, CO_2 and H_2O, with the production of heat. If there is more than the body requires for maintaining the temperature and activity the excess is stored away for future use—generally in regions where it is not likely to be disturbed by muscular activity.

Fat is not metabolized well if the carbohydrate metabolism is faulty.

During the metabolism of fat one of the intermediate steps results in the formation of acetone. Normally, this breaks up into CO_2 and water. If too much fat is taken this reaction is imperfect and the acetone is in excess. In order to dispose of this, with other acid products of the incomplete oxidation of fat, they must combine with alkaline substances in the blood and lymph before they can be eliminated by the kidneys. This is apt to result in a depletion of the alkali of the blood, causing an acid condition known as *acidosis*. So little reserve alkali is available to combine with the CO_2 this waste product is not properly eliminated. A carbon-dioxid poisoning, even death, may ensue.

Carbohydrate Metabolism.—The carbohydrate metabolism is very complex. They are used almost entirely for heat production and muscular work.

The digested carbohydrates are temporarily stored in the liver and muscle cells as glycogen—a form of starch. They may be transformed back to sugar by an enzyme in the cells, and they must finally be oxidized to release their potential energy as heat or motion. If the carbohydrates are not oxidized they appear in the urine as sugar.

Some of the steps appear to be the conversion, by digestion, of starch and sugar into dextrose; absorption of dextrose into the blood which enters the liver; absorption of dextrose into liver cells and its conversion into glycogen. During periods of muscular activity the glycogen in the muscles diminishes, to be again increased during rest. In the blood there is normally found 0.08 to 0.10 per cent of sugar. When this passes into the muscle cells the percentage in the blood falls and the liver cells reconvert some glycogen into dextrose which goes into the blood, to replace the amount used by the muscles. During muscular activity intracellular enzymes are supposed to convert the contained glycogen into sugar with subsequent oxidation—the development of heat and motion and the eventual release of CO_2 and water.

Numerous organs seem to be concerned in regulating carbohydrate metabolism. The secretion of the posterior lobe of the pituitary gland, the adrenals, the islands of Langerhans (insulin), all seem to exert an influence.

Centers in the medulla also operate, as well as the hepatic plexus of the autonomic nervous system.

An amount of carbohydrate food in excess of the body requirement is apt to be stored as fat. This fat can be utilized for heat and energy production if the daily supply of carbohydrates falls below the body needs.

As long as the organism is alive, metabolism is more or less active. When it stops, death ensues.

The vigor with which metabolism is carried on measures the speed of living. A considerable degree of vigor is necessary to health. Various conditions influence metabolism. In hyperthyroidism, the process is much increased, with the reverse in a deficiency of the thyroid secretion. Exercise increases both anabolism and katabolism with consequent increase in the elimination of CO_2 and H_2O.

The nitrogen eliminated is also increased, but not markedly unless the carbonaceous food is insufficient to provide for the additional oxidation so that proteins have to be utilized to provide fuel. Then, the output of urea is increased.

During sleep the amount of nitrogen waste is about the same as when awake, but the CO_2 output is less.

Low temperature increases the output of CO_2, but not of urea, though it is claimed, no increase occurs unless shivering takes place. Shivering makes for increased muscular work, which increases oxidation.

Animal Heat.—The food we eat does more than provide for growth and repair, as it furnishes the means by which heat, motion and thought are produced. Foods possess what is called "potential energy," measured by calories, but the liberated energy may be in the form of heat, kinetic energy or secretion. The different forms of energy are interconvertible as seen above. All oxidative processes are accompanied by the development of heat, so the work of the cells results in heat or its equivalent. Only about one-fifth of the energy developed is in the form of mechanical energy or motion, so only one-fifth of the food taken results in muscular work. The rest of it goes to heat.

The force developed in this way is measured in terms of "grammeters." A *grammeter* is the amount of energy needed to raise 1 kilogram of weight a distance of 1 meter. Foster calls 150,000 grammeters a good day's work. This is roughly equivalent to a man weighing 180 pounds climbing a mountain 5000 feet high in a day.

Body Temperature.—If one "takes his temperature" with a clinical thermometer, he finds it to be essentially the same, morning, noon and night; whether the out-door temperature is 20° below zero, or 115° in the shade. The body temperature in man is 98.6° F. or 37° C., and this record persists in health regardless of the surrounding conditions. There is some wonderful mechanism to insure this, some means of regulating the body response to its environment.

Man is called a "warm-blooded" animal as distinguished from the frogs, fish and reptiles that are "cold blooded." These latter change their temperature with their surroundings, but man maintains a relatively high temperature regardless of that surrounding him.

It has been seen that the potential energy of foods becomes either heat or kinetic energy when oxidized in the body cell. According to the activity therein, more or less heat is secreted or thrown off from the glands and muscles. By joint friction, respiration and cardiac activity, additional heat is produced.

The highest temperature in the body is in the blood of the portal vein, because of the great glandular activity of the liver.

While the temperature of the body is always essentially the same, there is a small variation of a degree or so, in different parts of the body, at different times of day and with different external temperatures. The rectal is a degree higher than the temperature in the mouth; that in the mouth is higher than in the axilla; the evening shows a higher temperature than the early morning; a surface exposed to the cold has a lower temperature than one that is protected.

Heat production is called *thermogenesis;* heat loss is *thermolysis;* heat regulation is *thermotaxis.* By thermotaxis, thermogenesis is balanced by thermolysis, so the body remains at the normal temperature, and neither force runs wild.

In fevers, either thermogenesis may be increased or thermolysis diminished, so the temperature rises.

Muscular and glandular activity in making heat are governed by centers in the spinal cord. It is thought these centers maintain a fairly constant production of heat, but the higher centers in the brain may reflexly incite them to greater or less activity.

Heat is lost by various means. About 85 per cent is lost by radiation and evaporation from the skin. Some 12 per cent is lost in the lungs by warming the inspired air and evaporation. A small amount is discharged in the urine and feces. Contact with colder objects abstracts heat from the body by conduction. Heat is lost more rapidly when the body is unclothed, as then the layer of dead air between skin and clothing is lacking.

Cold moist air and cold water contact lowers the temperature. A short cold plunge at first chills the body, driving the blood from

the surface capillaries, but this is shortly followed by a reaction through increased heat production reflexly.

Heat is lost when the internal temperature is raised and the external temperature is lowered. Its loss is greater in small bodies than in large ones, because the surface is relatively larger in small animals. Infants need more clothing for this reason than adults and larger children. As women have more subcutaneous fat, and fat is a poor conductor of heat, they can keep warm with less clothing than can men.

The greatest factor in equalizing heat production and heat loss is the blood. If a part is cold, more blood sent to it will increase its warmth. If the body surface is exposed to cold, as at 60° or less, the arterioles of the skin contract and the blood goes to the interior regions, where it will not be cooled. Shivering occurs, which by muscular activity promotes heat production. Between 60° and 70°, there is more or less blood in the skin, with the normal distribution between skin and internal organs at 66° to 68°. From 70° to 90°, more blood comes to the skin, the sweat glands become active and perspiration is induced with resulting evaporation which cools the surface. The effect of evaporation may be observed by placing a few drops of ether or gasoline on the skin and noting the chilling of the surface as it evaporates.

Nature goes to much trouble to ensure the regulation of the body temperature by automatic nerve centers which increase heat production when the surroundings of the body would injuriously lower the temperature, and inducing perspiration and evaporation when the outside temperature becomes higher and liable to interfere with health. It is thus seen how important the function of thermotaxis is in the economy of the body.

QUESTIONS.

Define "calories."

Define "vitamins."

Define metabolism.

What quantity and proportions of the various classes of food are necessary in an average diet?

If much muscular work is done, which food element should be increased over the amount needed by a person engaged in a sedentary occupation?

What is "nitrogen equilibrium"?

How is the heat of the body maintained when the outdoor temperature is zero?

How is the body kept at a normal temperature when an outdoor thermometer reads 110° F.?

What is "basal metabolism"?

CHAPTER XIII.

THE ORGANS OF EXCRETION AND ELIMINATION.

The metabolic processes of the body which include building-up and breaking-down produce a large amount of waste. These wastes are distinguished from the waste of the food which is thrown off through the rectum, having never really entered the body, by the fact that they are in the blood stream, and must be eliminated through the mediation of the microscopical tissues.

The CO_2 is largely taken from the blood in the lungs, but the nitrogenous wastes, those produced by the breaking-down of proteins, are still to be disposed of. Incidentally, this group of waste products, and there are many, is capable of doing much harm to the organism, if retained. The principal organs concerned in this work are the liver, kidneys and skin. The work done by the liver in forming urea has already been considered. This urea is thrown into the blood, and circulates through the body, but at each heart beat, a certain amount of blood goes to the kidneys, and there the further elaboration and elimination take place, with the subsequent ejection of the waste as *urine*.

THE KIDNEYS.

These two compound tubular glands, brownish in color, oval in shape, with a resemblance to a bean, are located about the level of the waist, or in the lumbar region, but *not* in front of the sacrum.

They are behind the peritoneum, surrounded by a mass of fat and loose areolar tissue, which with the renal artery, vein and nerve help to prevent their downward displacement. The fascia covering the kidney is connected with the fascia of the quadratus lumborum and psoas magnus muscles, and with these to the aorta. The pressure of surrounding organs is another factor in holding the kidneys in place.

The upper border is on a level with the upper border of the twelfth thoracic vertebra, while the lower border is level with the third lumbar vertebra. The right kidney is a little lower and wider than the left. They are about $4\frac{1}{2}$ inches long, 2 inches wide and $1\frac{1}{2}$ inches thick. The weight varies from $4\frac{1}{2}$ to 6 ounces.

Covering the kidney is a fibrous capsule which continues from the outer surface to the pelvis, lining it as well as the infundibula and the calyces. On the inner and forward part is a depression

called the *hilum*, from which arise the *ureters*, and through which pass the renal artery, vein and nerve. (Fig. 300.)

On cutting the kidney lengthwise, it is found to be of a dark red color, with pyramidal spaces of lighter red. (Fig. 301.)

The outer border is the cortex or medullary portion with the pyramidal portion toward the center. The latter opens into a cavity, called the *pelvis of the kidney*, from which also emerge the *ureters* or excretory ducts of the organ. Three short canals from the pelvis go toward the upper, middle and lower parts of the kidney. These are *infundibula*. Each divides into several smaller canals called *calyces*, which receive the apices of the pyramids.

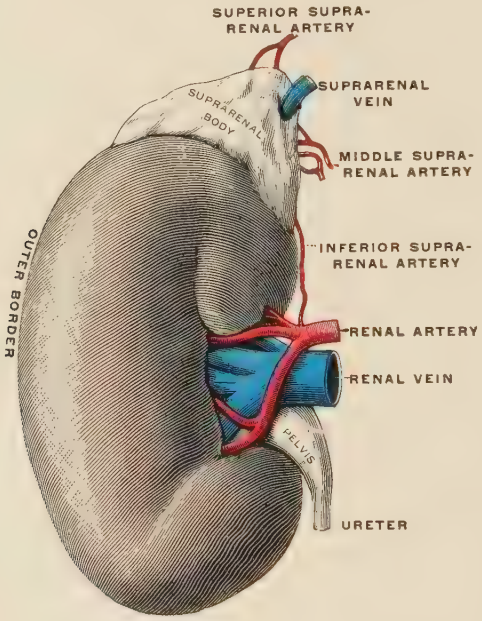


FIG. 300.—Right kidney, ventral aspect. (Testut.)

The cortical layer, about $\frac{1}{6}$ inch thick is of a reddish granular structure. It contains the essential, secreting portion of the kidneys, the *glomeruli*, with the convoluted tubules, bloodvessels and lymphatics in areolar tissue.

The Blood Supply of the Kidney.—The kidneys receive their blood supply through the *renal* arteries. These enter at the hilum and divide into numerous branches. Those going to the cortex take part in the formation of urine.

The Glomeruli.—The arterioles enters capsules, formed by the folded-in-ends of renal (uriniferous) tubules. Here they wind into tufts, snarls or skeins, without forming a network. Emerging from

the capsule, the arteriole passes down and breaks up into a capillary network around the convoluted part of the tubule. From this network the venous capillaries emerge, and unite to form the renal veins at the hilum, going into the inferior vena cava.

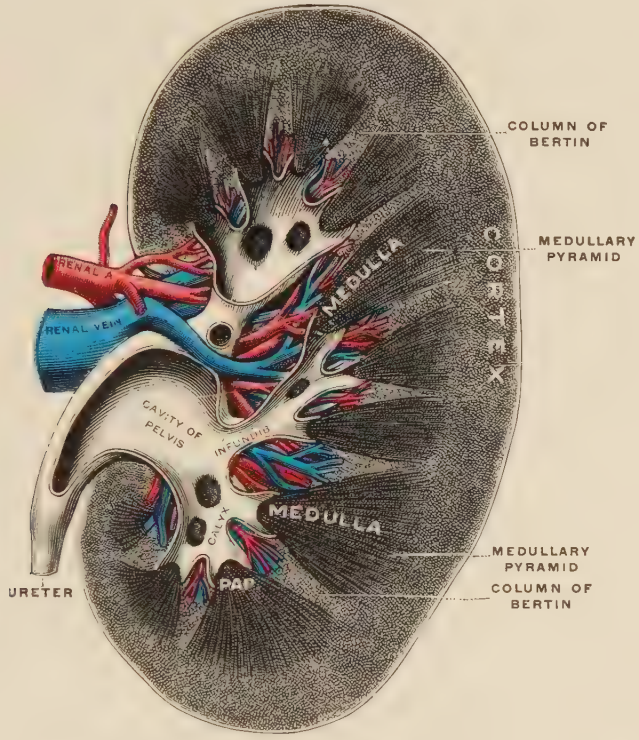


FIG. 301.—Vertical section of kidney, showing the secreting portion, the vessels and the beginnings of the ureter. (Testut.)

Uriniferous Tubules.—The renal or uriniferous tubules begin as invaginated ends of tubes. When they leave the glomeruli (capsules) they take an extremely tortuous course, finally opening into the apices of the pyramids at the end of a straight portion of the tube.

The tubules are lined with epithelial cells, flattened in places, but mostly secretory, nucleated cells. (Fig. 302.)

Mechanism of the Formation of Urine.—It is thought that within the Malpighian corpuscle or glomeruli the blood-pressure is higher than it is outside, because the caliber of the arteriole on leaving is less than it is on entering. This produces a filtering effect in which water and soluble mineral salts from the blood pass out into the renal tubule. In the convoluted portion of the tubule the epithelial

cells take the urea from the blood and send it into the tubule, where it is dissolved and carried along. Possibly, some of the water is reabsorbed as it passes along the extremely long tubing, thus increasing the specific gravity of the urine that has been formed.

The Malpighian corpuscles are from $\frac{1}{250}$ to $\frac{1}{100}$ inch in diameter. The renal tubules are from $\frac{1}{2000}$ to $\frac{1}{200}$ inch in diameter.

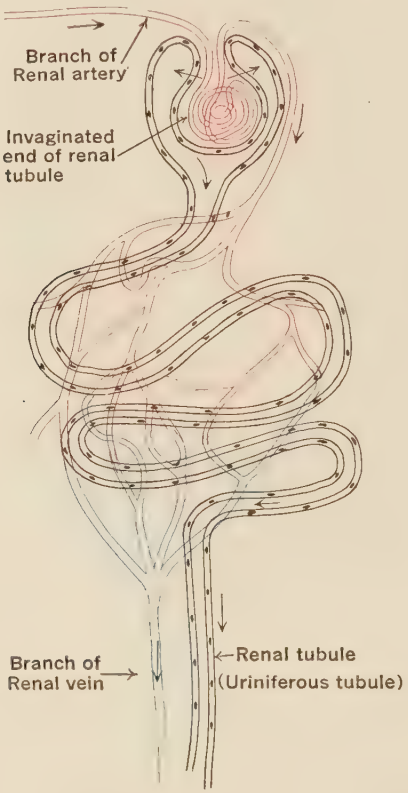


FIG. 302.—Diagram of Malpighian corpuscle and uriniferous tubule, with arteriole forming a snarl or intricate loop in the beginning of the tubule.

This arteriole does not break up into a network in the corpuscle, but after leaving the latter forms a capillary network around the convoluted tubule.

From these capillaries the venous radicles arise, which, uniting, eventually form the renal veins.

From the blood the route of the urine is, through the glomeruli, the convoluted tubules, the straight tubules, the calyces, the infundibula, to the pelvis of the kidney. Thence through the ureters to the urinary bladder and out through the urethra.

The Urine.—Urine is a fluid of light yellow color, acid reaction, specific gravity of 1020, and amounting in twenty-four hours to

1500 cc. Among its constituents are: Urea, uric acid, chlorine, phosphoric acid, sulphuric acid, creatinin, hippuric acid, oxalic acid, several nitrogenous acids, fatty acids, dissolved nitrogen and carbon dioxide, pigments, as urochrome and urobilin.

Under pathological conditions, sugar, albumin, bile, hemoglobin, acetone and other substances may be present.

The composition of urine varies according to different conditions of nutrition, exercise, sleep, age, sex, diet, respiratory activity, condition of skin and emotions.

The principal ingredient is urea, which is found in the blood at all times. A certain percentage is always present, and if the kidneys function properly, all in excess of this normal amount is removed.

The presence of urea in the blood seems to be the stimulus which excites the activity of the epithelial secreting cells. The greater the amount of blood with its contained urea that passes through the kidney, the greater the activity of that organ.

The amount of blood that passes through is influenced by several factors.

1. External temperature. Cold sends the blood from the skin to the interior organs, while heat reverses the process.

2. By the amount of water ingested. The more water, the more urine.

3. By the amount of protein food. (An excess of protein beyond the needs for repair or building must be eliminated.)

4. By nervous excitement. This increases the amount of urine, but lowers the percentage of solids.

5. By muscular activity. The greater the tissue metabolism, the more urea is formed and eliminated.

After the urine collects in the pelvis of the kidney it passes into the *ureter*, a tube about 18 inches long which goes to the urinary bladder. It penetrates the bladder obliquely, so if the bladder becomes distended the opening from the ureter is automatically closed, and regurgitation to the kidney prevented. As the middle coat of the ureter is muscular, a peristaltic wave carries the urine along, regardless of the position in which the body is placed.

The Nerve Supply of the Kidneys.—The kidneys are controlled by the autonomic system. Through the lesser splanchnic nerve the preganglionic fibers pass into the renal ganglion, from which emerge the postganglionic fibers to form the renal plexus. The secretory and vasomotor fibers are supposed to be regulated by a center in the medulla, though there may be other centers in the lower part of the spinal cord.

THE BLADDER.

This is a reservoir for urine, where it is retained until it is convenient to expel it. It is ovoid in shape, holds about a pint, and is located in the front part of the pelvic cavity.

There are three coats, the outer of peritoneum, the middle of plain muscle fibers, and the inner of mucous membrane.

The muscular coat is in three layers, with the fibers running in various directions. When it contracts the contents of the bladder are compressed in all directions.

The outlet of the bladder is embraced by a thick band of unstriped muscle tissue, the *sphincter vesicæ*. This is usually in tonic contraction, so preventing the involuntary escape of urine.

When the bladder has become moderately full, the desire to expel its contents arises. The act of expelling is micturition, and involves the relaxation of the sphincter, the contraction of the muscular wall of the bladder, aided by the contraction of the abdominal wall.

A slight contraction of the abdominal wall compresses the bladder, and the relaxation of the sphincter allows the urine to pass out.

The *urethra* is a short tube that leads outward from the bladder.

THE SKIN.

The skin or integument is the external covering of the body, varying in color, texture and thickness.

According to the amount of pigment, the color varies from milk-white to black, mahogany, yellow or brown.

It varies in texture from a satiny smoothness to a coarse horny roughness. In thickness, it varies from $\frac{1}{12}$ to $\frac{1}{2}$ of an inch.

It has furrows everywhere, which differ in character in different individuals, so the markings of the thumb, for instance, serve for identification. The structure of the skin is in two parts, the corium or true skin, or cutis vera, and the epidermis, scarf skin, which is external to the former. The *corium* is the active part of the skin, and is very complex.

External to and connected with the superficial fascia is a network of areolar tissue, which allows the skin to move freely on the underlying parts, and which serves as a bed for numerous organs.

In this bed are the branchings of the arteries, veins and lymphatics that supply these parts and drain them. An abundant blood supply is evidenced by the fact that it is impossible to pierce the skin anywhere without drawing blood. Scattered through the areolar tissue is its specialized form, adipose, as masses of fat, in varying degree, but always present.

On the summits of the furrows are elevations called papillæ (Fig. 303 and 304), and in the papillæ are the end organs of the sense of touch, or Pacinian corpuscles (tactile corpuscles). They are thickly scattered on the skin, with very few areas without them. The endings of the sensory nerves vary in structure, and it is possible there are different ones for each sensation of heat, cold, pressure and pain.

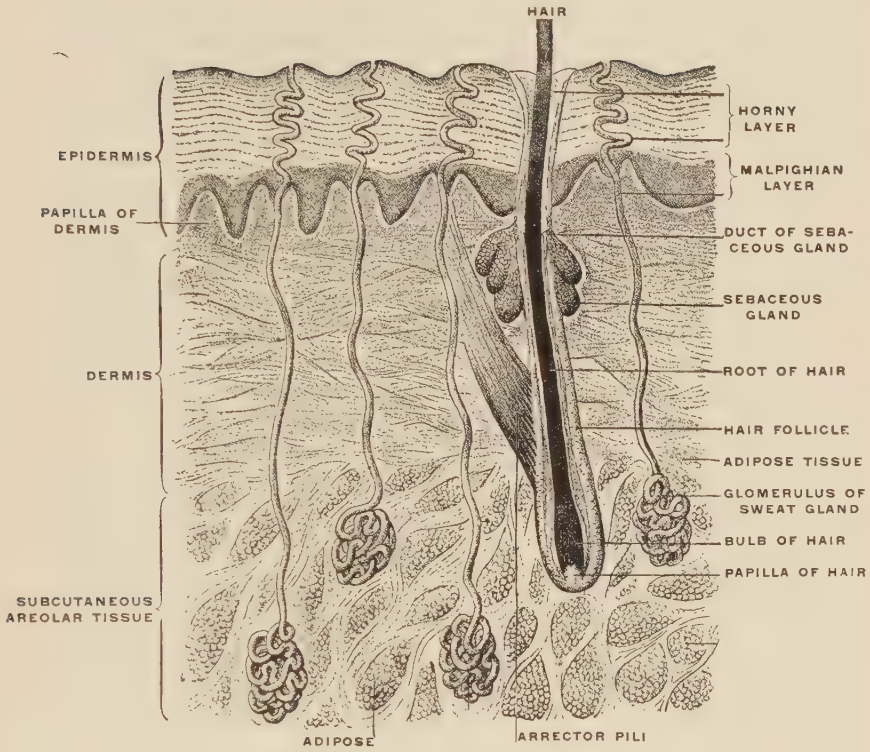


FIG. 303.—Vertical section of the skin. (Testut.)

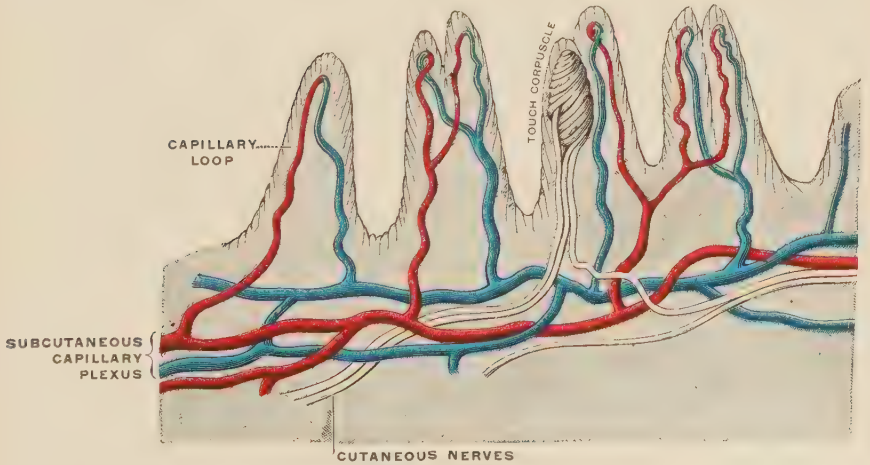


FIG. 304.—Papillæ of the skin, showing the arrangement of the vessels and nerves. (Testut.)

The tactile corpuscles are laminated like an onion, with from forty to sixty coats. The nerve fiber penetrates to the middle of this bulb, and finally ends in bulb-like processes.

Fig. 304 shows the capillary loops in the papillæ from a network in the cutis vera. Branches go to the fat, sweat and sebaceous glands.

Sweat Glands.—The sweat glands are true excretory organs in the skin, to the number of 2,500,000, as estimated. They are tubular glands, coiled up at the inner end to provide greater secreting surface, and opening on the surface of the skin, as the pores. The coiled tube is lined with columnar epithelial cells, which take from the blood, water and various salts, sodium chloride largely, and some urea and uric acid, etc. The sweat is more or less profuse according to circumstances, but an average amount is over 2 quarts in twenty-four hours.

It is salty in taste, of acid reaction and characteristic odor. By the secretion of visible perspiration and its evaporation, the surface of the body is cooled, and its temperature lowered. This occurs when the external temperature is 70° F. or more, or when the skin temperature is increased by muscular exercise.

An occasional person has been found in whom the sweat glands were lacking, necessitating the use of external applications of water when the body temperature threatened to rise unduly.

Secretory nerves from the sympathetic rami communicantes are distributed to these glands. The control seems to be automatic and in the medulla.

Except for a few areas the whole skin is studded with *hairs*, varying from a fine down (lanugo) to the stiff hairs of the eyelashes and beard. They vary much in length, thickness and coloring. Straight hair is cylindrical on cross-section, while curly hair has flat places on the curves. A hair consists of a shaft and the root or bulb. The bulb of the hair is whiter and softer than the shaft, and is lodged in an involution of the epidermis, called a follicle. The bulb contains various epithelial cells some of which contain pigment, which gives the color to it. (Fig. 303.)

The structure of the follicle is rather elaborate, and the shaft of the hair only less so.

The shaft consists of a central pith or medulla, a fibrous covering, and an external cuticle of imbricated scales. In the fibrous portion between the cells, are pigment granules in dark hair, or air spaces in white hair.

Passing between the surface of the corium and the follicle are small muscles which by their contraction erect the hair. The bristling of hairs on the back of a dog's neck when he is angry shows their action more vividly than is possible in human beings.

Sebaceous Glands.—Opening into the hair follicles are sebaceous glands, compound racemose in form which secrete oil, serving to prevent dryness of the hair and skin. These glands are also in various other places where little hair is found, as on the nose and eyelids (Meibomian glands).

Nails.—Modifications of the epidermis, or appendages of the skin are the nails. The body of the nail is translucent, showing the blood beneath, except at the upper end where a half-moon shaped area, the *lunula* is more opaque. The free edge of the nail overhangs the end of the toe or finger. The root of the nail is imbedded in a groove of the skin, while the nail-bed holds the nail closely adherent. The proximal part of the bed is the *matrix*, at which growth takes place, requiring some three months for a complete new nail to grow to the free edge.

Epidermis.—The second part of the skin is the epidermis or scarf skin, or cuticle. Two strata, the Malpighian layer and the horny layer *stratum corneum*, arise from a single layer of columnar cells resting on the corium. The Malpighian layer consists of some four layers, the layer of parent cells above mentioned, then polyhedral prickle cells, with pigment, overlaid by granular cells, and a series of transparent cells, called the "stratum lucidum." These are all nucleated cells, and the upper layers become merged with those of the horny layer which lose their nuclei, become scale-like at the surface and are shed.

The bed of the nail is a part of the Malpighian layer.

Functions of the Skin.—Some of these have been considered, chief of which is the regulation of the heat of the body; the prolongation of the brain to the surface by the sensory nerves, and the excretion of waste products. Through the sweat glands the skin can throw off much of the nitrogenous waste of the body, serving vicariously for the kidneys when the latter are unable to function.

It is a matter of common knowledge that when the body perspires freely, the secretion of urine is lessened in amount, and conversely, when the surface is chilled, so perspiration is checked, the amount of urine is increased.

The other uses are more mechanical, as the protection of underlying parts, preventing the escape of fluids, as blood and lymph, and preserving the contour of the body.

QUESTIONS.

What is urea? What is urine?
Locate the kidneys. What is their function?
How does the kidney function compare in importance with that of the stomach?
What are the functions of the skin?
Describe the "cutis vera."
Where are Pacinian corpuscles found?

CHAPTER XIV.

THE SYMPATHETIC OR AUTONOMIC NERVOUS SYSTEM.

The sympathetic or autonomic nervous system has to do with the control of the so-called *vegetative processes* of the body. All the involuntary or smooth muscle fibers in the walls of bloodvessels and of the hollow viscera in the body are governed by the sympathetic. All the epithelial cells in glands or viscera have fibers from this system to control their activity.

It has been observed that the muscles of the skeleton are controlled by nerves from the brain and spinal cord, with the axones coming directly from the neurons of those regions. They have no independent action, but their movements are initiated either as a reflex from some external agency or through the will.

The non-striated muscles and glandular epithelial cells receive their motor impulses more indirectly. From cells in a small area in the mid-brain; from the region of the medulla; from the lateral horns of the gray matter of the spinal cord, extending from the second thoracic to third lumbar and from the ventral horns of the second, third and fourth sacral segments of the cord, impulses of the sympathetic emerge.

From these cells of the cerebrospinal axis, fine white fibers (white rami communicantes) pass outward, along with the anterior nerve roots, and sooner or later arborize around cells in a sympathetic ganglion. These are called "preganglionic fibers." From the cells of the ganglion, non-medullated gray fibers emerge as axones (gray rami communicantes) and pass to epithelial glandular cells, or to the non-striated muscle in the walls of bloodvessels or the hollow viscera. (Fig. 305.)

As the cells from which the preganglionic fibers emerge cannot originate impulses, there must be some outside influence to initiate activity. This influence is generally reflex, as in the case of the smell of food exciting the secretion of saliva, or through emotions. This latter is shown by the change in the rhythm of the heart by the emotion of fear or anger. The pressure of food in the stomach by which the gastric secretion is increased, is an instance of a sensory impulse from without initiating activity. The varying chemical composition of the blood may also start activity.

It thus appears that the activity of this part of the nervous

system is, in the main, reflexly excited, with modifications by various emotional impulses.

Because it is more or less independent of the will and is somewhat self-regulatory, it is called the "autonomic nervous system." It is distributed to the autonomic tissues.

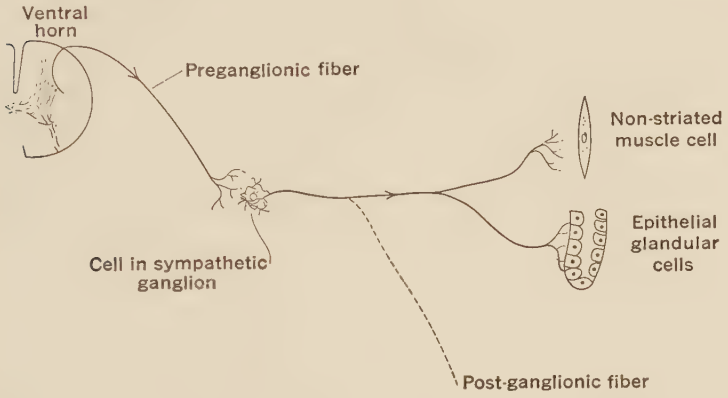


FIG. 305.—Diagram showing connection of cerebrospinal and sympathetic nerves.

Location and Arrangement.—A ganglion is a pinkish-gray mass of neurons, with cells, dendrites, axones and bloodvessels enclosed in a fibrous capsule. The cells, also, have fibrous capsules, from which a coating extends over the axones. There is no medullary sheath for these postganglionic fibers, so they are gray in color.

Two kinds of fibers are described: (1) The *gray rami communicantes* which pass out to join cerebrospinal nerves, going with them to the skin where they are distributed to the walls of the bloodvessels and to the epithelial cells of the sweat glands in the respective neighborhoods.

2. The *rami viscerales,* that go directly to the various viscera to control their blood supply and glandular activity.

There are three groups of ganglia.

On each side of the front of the spinal column is a chain of ganglia, extending from the base of the brain to the coccyx. These are the *vertebral ganglia.* While there are thirty-one pairs of spinal nerves, these number twenty to twenty-three.

Three pairs of ganglia, the superior, middle and inferior cervical are in the neck; 10 or 11 are in the thoracic region; and the rest are in the lumbar and sacral region, with a single ganglion in front of the coccyx (ganglion impar).

The ganglia are connected by the gangliated cord which extends from the superior cervical to the ganglion impar, making an appearance like a chain of beads with a pendant.

The superior cervical ganglion is connected with the four upper cervical nerves which form the cervical plexus, and with several cranial nerves, including the vagus. It sends filaments to the upper cardiac nerve. (Note its relation to the suboccipital muscles.)

The middle cervical ganglion connects with the fifth and sixth spinal nerves, and with the superior and inferior ganglia. It sends branches to the thyroid gland and to the upper cardiac nerve.

The inferior cervical ganglion connects with the middle ganglion, the seventh and eighth cervical and first thoracic spinal nerves. It sends branches to the cardiac nerve.

Physiologically, the cervical sympathetics are very important, and a careful study of their relations to surrounding and distant structures is necessary for those engaged in physio-therapeutic work. It is particularly desirable to study the effects produced through them by excessive muscular tension of the back of the neck.

In the abdominal cavity is a group of ganglia called *prevertebral.* They include the semilunar, the renal, the superior and inferior mesenteric and the hypogastric. (Fig. 306.)

Besides the above collections, each organ has one or more groups of cells within its substance, which influence its activity, even when shut off from the other two groups. They seem to work automatically and with a rhythm peculiar to each organ. These are called *sporadic, intrinsic* or *peripheral.*

Among the sporadic ganglia are the *ophthalmic,* back of the eyeball; the *sphenopalatine,* at the base of the brain; the *otic,* below the foramen ovale (between the middle and internal ear); the *submaxillary,* near the salivary gland of that name; the *cardiac,* in the walls of the heart; the *plexi of Meissner* and *Auerbach* in the walls of the stomach and intestines, and the *pelvic,* near the base of the bladder.

Solar Plexus.—Just a little below the diaphragm there is an aggregation of nervous tissue, called the *solar plexus* or *abdominal brain.* It consists of preganglionic fibers in the *vagus,* the greater and lesser splanchnic nerves, and visceral fibers from the abdominal ganglia. It controls the vasomotor, secretory and motor activity of the abdominal viscera.

Rami Efferentes.—As the motor and sensory, the motor and intellectual centers in the brain are connected by association neurons, and those in the spinal cord are connected by the correlation neurons, so the more centrally located autonomic ganglia have interconnecting cords, which unite them to the more peripheral ganglia. These cords are white preganglionic fibers from the cells in the gray matter of the cord, which pass out with the anterior roots of the spinal nerves, go into the vertebral ganglia, arborizing around the cells, from which gray fibers emerging (*rami efferentes*), go to the peripheral ganglia.

From the fifth to the tenth thoracic segments the interconnecting cords become the *greater splanchnic nerve*. From the ninth and tenth thoracic comes the *lesser splanchnic*, while the *inferior splanchnic* is derived from the second and third lumbar segments. In this way the greater splanchnic nerve connects the spinal cord with the semilunar and superior mesenteric ganglia, the lesser splanchnic connects it to the renal ganglion and the inferior with the inferior mesenteric.

In the thoracic region white preganglionic fibers come from the spinal cord and communicate with ganglia on the same level or turn upward or downward to those on other levels.

The fibers in the upper thoracic region communicate with the cervical ganglia and so influence the heart action.

By these means the preganglionic fibers from the thoracic and lumbar spinal cord become associated with all the vertebral and prevertebral ganglia. The gray rami that arise in the cells of these two sets of ganglia enter the cerebrospinal nerve trunks, going with their motor and sensory divisions to the walls of the bloodvessels, the sweat glands, the thyroid, the adrenals, etc., and serve as inhibitory nerves to the muscles of the hollow viscera.

The visceral fibers which arise from these ganglia go to the epithelial cells of the viscera in the thorax and abdomen.

In the sacral region a like arrangement exists to control the pelvic viscera.

In association with the motor fibers, as above, there are afferent or sensory fibers which carry sensations from the thoracic and abdominal organs. In health very little cognizance is taken of reports from these viscera, but in pathological conditions these fibers may carry impulses which register in the sensory areas of the cortex as extreme pain. Such sensations from the abdominal organs are apt to depress the psychic centers much more than the same amount of pain elsewhere.

Fear, anger and other emotions, mediated in the brain have definite effects upon the various organs. Fear blanches the skin, weakens the muscles, especially the extensors, and changes the rhythm of the heart. It may stop digestion midway. Fear is a mental emotion, located in the sensorium, but working out through the blood supply of these various parts.

Relation of the Sympathetic System to the Functions of the Body.— Under normal conditions it is supposed the sympathetic or autonomic nerves are always excited reflexly and involuntarily. Sensory impressions that initiate the reflexes are visual, auditory, olfactory, gustatory, pressure, temperature, pain, hunger, thirst, etc. The response that completes the reflex may be excitatory or inhibitive. The excitatory response may be either motor or secretory. The motor responses may be in the sphere of the vasomotor, cardiomotor, visceromotor or pilomotor phenomena.

The secretory response may be the production of the salivary secretion, gastric juice, pancreatic juice, bile, urine, sweat, etc. Or the response may be to inhibit motor or secretory activity.

Specifically, through the rami efferentes certain familiar phenomena occur.

The ophthalmic ganglion is in relation with the motor oculi muscle through connecting fibers. Its postganglionic fibers increase the tone of the sphincter muscle of the iris, regulating the size of the opening and the amount of light admitted to allow the perception of clear and distinct images.

The sphenopalatine ganglion is in relation with the facial nerve. Postganglionic fibers go to the lachrymal gland, inhibiting the constrictor muscles of the arterial supply, so allowing an increased amount of blood, and also stimulating the secretion of tears. As the facial is the nerve of emotional expression, it is easy to see the connection between sad emotions, their facial expression and tears.

Another postganglionic fiber goes from the above ganglion to the mucous membrane of the upper part of the respiratory tract, inhibiting the circular fibers, so increasing the amount of blood in the membrane, at the same time stimulating the epithelial cells to secrete mucus. As there appears to be a reversed action between the vasomotor nerves in general and those in the cranium, the familiar cold in the head from suddenly chilling the surface seems logical. That is, if cold strikes the skin the vasomotor nerves are stimulated to contract, so driving the blood from the skin to the interior. The reverse of inhibiting the vasoconstrictors of the cranial vessels would send an excess of blood to the mucous membrane of the nose and throat, with an increased secretion of mucus—possibly including that of the eye and lachrymal glands.

The glossopharyngeal nerve comes into relation with the otic ganglion, and the postganglionic fibers act to increase the secretion of saliva. Hence, the taste of food starts or increases the secretion of saliva to digest it.

The vagus nerve comes into relation with the ganglia in the walls of the heart, stomach and intestines. The postganglionic fibers from these ganglia inhibit the tone of the heart muscle and its power, so slowing the action of the heart. By inhibiting the contraction of the muscles in the wall of the esophagus at its lower end, the food is allowed to pass into the stomach. There is an increase in the contraction of the muscles in the walls of the bronchi and of the stomach and intestines, etc.

Through this slowing or inhibition of the heart the serious effect of a blow over the solar plexus may be explained.

The preganglionic fibers from the segments of the cord below the fifth dorsal are related to the semilunar, renal, superior mesenteric ganglia, etc., and from the neurons leaving these ganglia, fibers, as

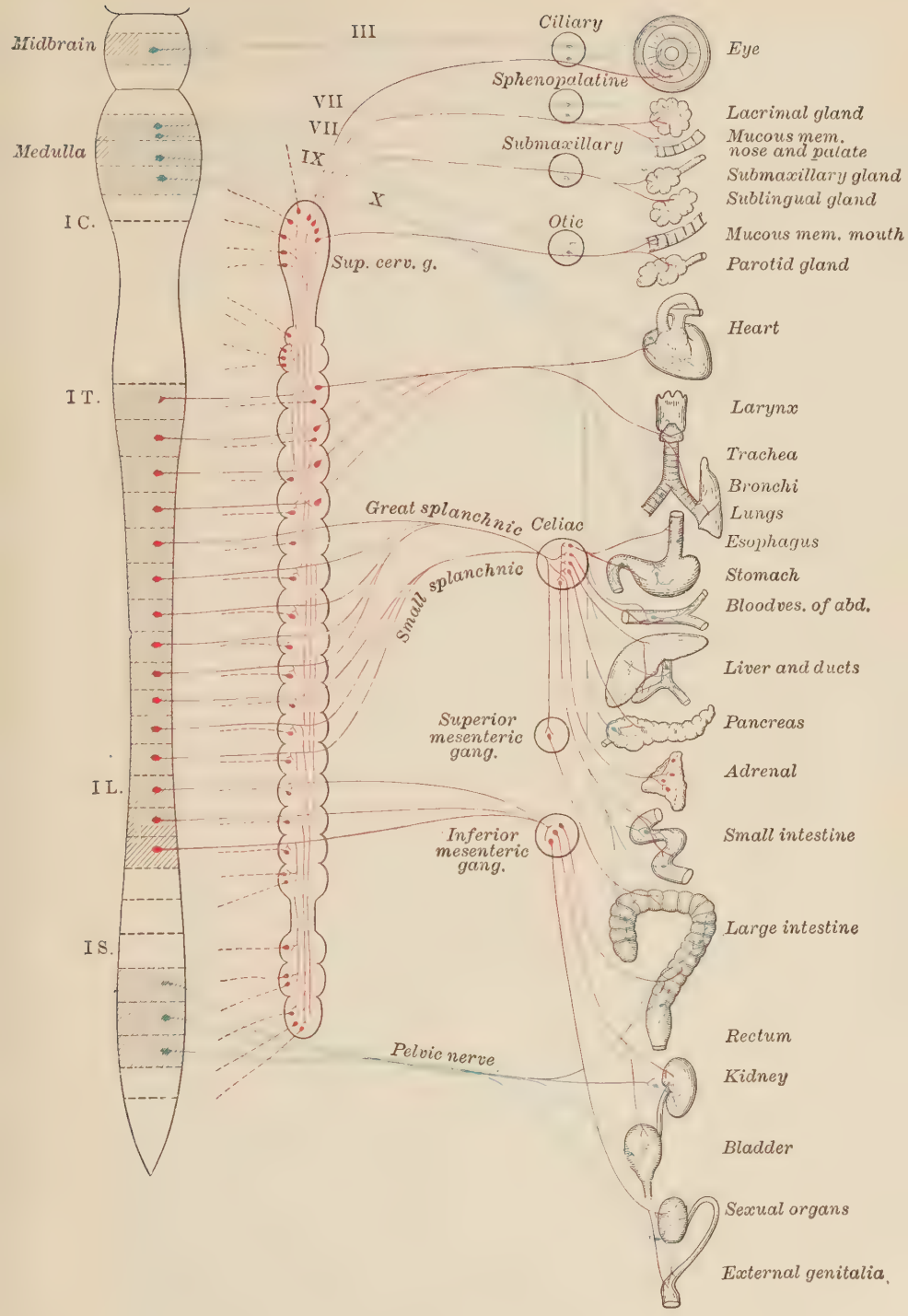


FIG. 306.—Diagram of efferent sympathetic nervous system. Blue, cranial and sacral outflow. Red, thoraco-humeral outflow. ------, postganglionic fibers to spinal and cranial nerves to supply vasomotors to head, trunk and limbs, motor fibers to smooth muscles of skin and fibers to sweat glands. (Modified after Meyer and Gottlieb.)

vasoconstrictors, go to control the bloodvessels of the spleen, kidneys, liver, stomach and intestine.

It should be observed that there is an intimate relation between the tonus of the skeletal muscles in a given region, and the tonus of the visceral muscles in the same region. Consider the relationship between bad posture and poor digestion from this standpoint—the flaccid muscles in the scapular regions and in the abdominal wall and the reflection of weakness in the organs concerned in digestion.

The postganglionic fibers in relation with the lumbar and sacral nerves (the region from which the great sciatic emerges) influence the contraction or dilatation of the bloodvessels of the skin over the lower extremity and control the secretion of sweat in that region. (Fig. 306.)

The Subconscious Mind.—The study of psychology and physiology meet in the consideration of the subconscious mind. What the conscious mind is to the cerebrospinal nervous life, the subconscious is to the sympathetic realm, or vegetative life. There is a widespread belief that the conscious mind can influence if not control the subconscious mind by means of suggestion; either from one's self or through another. The explanation of the wonderful apparent results of the "Coué" methods depends upon the fact that the control of the vital processes of life, respiration, circulation, digestion, assimilation, etc., are through the subconscious mind and its sympathetic servant.

QUESTIONS.

How does the autonomic part of the nervous system differ from the cerebrospinal portion?

In what way are the spinal nerves connected with the sympathetic ganglia?

How would you explain the phenomenon of blushing?

How is the amount of blood going to the stomach regulated?

Make a diagram showing the way sweat on the palms is produced

What are rami communicantes?

CHAPTER XV.

THE DUCTLESS GLANDS.

Reference has been made to *internal secretions* or those which are made by glands and pass out into the blood stream, as compared with those that are carried off through a duct, or the *external secretions.* It has been relatively easy to study the latter, experiment with them in laboratories, and determine their function with a fair degree of probable accuracy.

The study of internal secretions has been attended with much difficulty, and is still far from being complete. By removal of a gland it has usually been found that its secretion was essential to life. If only partially removed, the animals subjected to the test, showed the necessity for the secretion to influence growth, nutrition and development, mental and physical.

Another method of experiment has been the injection of the secretion into the circulation of healthy animals and noting the effect. Further light came from feeding the glands to animals in whom the same or another gland had been removed, and finding the apparent effects. The principal ductless glands are the *spleen, thyroid, parathyroids, thymus, adrenal, pituitary, pineal* and *gonads.*

The liver and pancreas also have internal secretions which have been discussed under those respective headings.

THE SPLEEN.

The spleen is a large ovoid body, situated in the posterior part of the abdomen, behind the stomach. It varies in size, in health, but is usually about 5 inches in length, 3 inches wide and 1 inch thick. It weighs about 5 ounces, is of a purplish-red color, friable and soft in consistency.

The blood supply of the spleen is very abundant, showing that its function is important, yet its removal has been followed by no permanent bad results. The venous blood from the spleen enters the portal vein, goes through the liver and thence to the vena cava.

In this venous blood are many leukocytes, but investigators have found out really little about the function of the spleen.

It seems to have some relation to the red corpuscles of the blood, and their hemoglobin, possibly destroying the corpuscles and transforming the hemoglobin. Removal of the spleen is followed

by an anemic condition which lasts but for a short time, with a return to the normal number of corpuscles after some months. Increased amounts of iron are said to be excreted, with a diminution in the amount of bile pigment. After a meal the spleen expands for four or five hours, then returns to its normal size.

The circulation of the spleen is supposed to be maintained by a local arrangement which makes it independent of variations of general blood-pressure.

During fetal life and soon after birth the spleen forms new red corpuscles, but this is not known to continue into adult life. The organ is larger in childhood and gets smaller after puberty. It has been suggested it may be concerned in the production of uric acid. The spleen may become much enlarged and hardened during malaria. It is also credited with influencing the psychic life in the way of depression and irritability.

The structure resembles in some respect that of lymph nodes, and as a whole rather like an enormous group of nodes.

THE ENDOCRINE SYSTEM.

The glands that are now to be described are supposed to have a definite inter-relation, and are designated as the "endocrine system." The activity of other organs is influenced by the secretions of these glands, the general name of "hormones" being applied to such secretions. Some hormones stimulate, others inhibit activity.

The Thyroid.—This is a gland lying on the lower part of the front of the larynx, and upper part of the trachea. (Fig. 307.) It has two lateral lobes connected at the lower part by an isthmus. Each is about 2 inches long, $\frac{3}{4}$ of an inch thick and $\frac{1}{4}$ of an inch wide. It is relatively larger in infants than in adults. It weighs about 1 ounce. It is divided into *lobules* by the prolongation inward of the outer fibrous coat. These in turn are composed of closed vesicles, which are lined with columnar epithelium, secreting a colloid material, a protein containing iodine.

Removal of the thyroid produces a state of chronic malnutrition. It has, therefore, a profound influence upon nutrition and development. Its secretion acts upon the body cells to increase metabolism.

Normal persons who take thyroid extract have the metabolic function increased with resulting increase in bodily heat and energy, and increased elimination of nitrogen and carbon dioxide. The stimulating effect may be so marked it is well described as a "kinetic urge" or desire for activity.

Abnormal growth of the thyroid produces *hyperthyroidism*, or *goiter*, or *exophthalmic goiter*, in which the heart rate is much increased, heat production much augmented, and psychic irritability

marked. If the metabolism of normal persons can be indicated by "40," that of such subjects might be indicated by "75."

Where there is atrophy of the gland or failure to develop, the condition known as *cretinism* develops. In this there is less metabolic activity than normal, the growth and brain development are stunted, so a child would be of scarcely higher grade than an idiot.

The gland extract administered early enough will start up the process of normal development, both physical and mental.

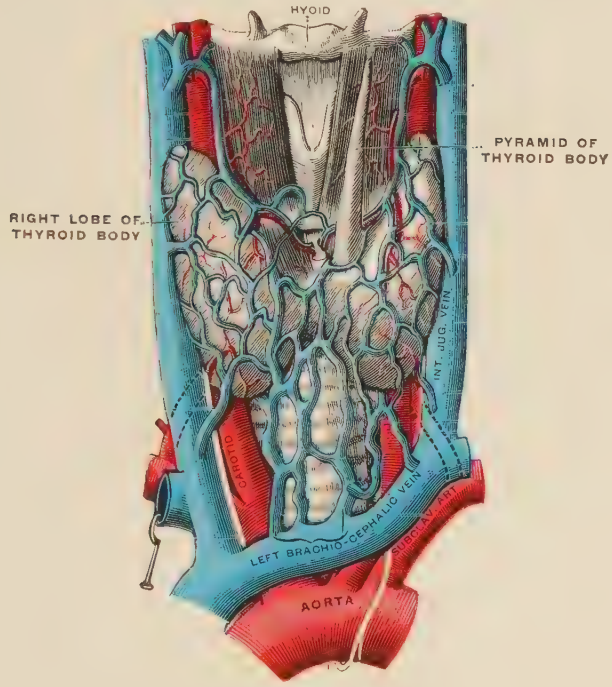


FIG. 307.—The thyroid body and the related bloodvessels. (Testut.)

When a large part of the thyroid is removed, in adults, the condition known as *myxedema* results. This exhibits lowered metabolism, lessened body heat, increased deposition of fat in the tissues, mental hebetude and lack of activity.

The Parathyroids.—These are four round bodies, about $\frac{1}{4}$ of an inch in diameter, closely associated with the thyroid, whose removal is followed by death from tetanus in a short time. It appears their function has something to do with preventing or neutralizing the accumulation of certain toxic products in the blood whose presence causes spasmodic contractions of muscles. They may influence or regulate the metabolism of calcium compounds, and also lessen the ability of the organism to take care of sugars.

The Thymus Gland.—This is situated over the upper part of the sternum. Its function is obscure, though it may be concerned with the process of growth. It is said to keep its size and activity until the age of puberty, and then to undergo a gradual atrophy. It is possible there is some reciprocal connection between its function and the development of the reproductive glands.

Adrenal Gland.—The adrenal bodies, or *suprarenal capsules* are conical shaped glands perched on top of the kidneys and imbedded in fat. Their removal from an animal is followed by its death, preceded by great prostration, muscular weakness and lessening of arterial tone. Impaired function or disease of the adrenals produces a complex known as "Addison's disease." Great muscular weakness, inability to digest food, diarrhea and vomiting, feeble heart action, low blood-pressure and a bronzing of the skin characterize this condition. There is a loss of tone of all muscles, and, finally, respiratory paralysis. Adrenalin is used to render areas bloodless by constriction of the muscle in the artery walls. Injections of the gland substance into the circulation of a healthy animal results in slowing the rate of the heart beat and a rise of blood-pressure. The secretion, *epinephrin,* seems to have some relation to the regulation of the sugar supply or sugar consumption of the body.

Strong emotions of fear or anger increase the amount of adrenal secretion. This may mean that when a person is afraid or angry, the increased epinephrin may so stimulate the tonicity of the skeletal muscles, increase the blood going to the nervous system, and make more glycogen available for the muscles, he will be able to make the natural effort to escape the danger or protect himself by an offensive.

The Pituitary Body or Hypophysis.—This gland is found at the base of the brain, in the sella turcica of the sphenoid bone. It has an anterior lobe that is fairly large, and a much smaller posterior lobe.

When extracts of the posterior lobe are injected the heart beat is slowed and the blood-pressure raised. It assists in the regulation of carbohydrate metabolism.

Most of the involuntary muscles of the body are stimulated as well as some of the glands. The general metabolism is stimulated, particularly through the increased glycogenolysis, by which the glycogen in the liver is made available for use in the muscles.

The secretion of the anterior lobe has some effect upon nutrition, but just what, is a subject for further investigation. It probably promotes the growth and development of the organs of reproduction. Its removal from an animal results in its death in a few days, but death is preceded by a lowering of temperature, rapid emaciation, diarrhea and unsteady gait.

If the pituitary gland becomes overgrown there is an increased

growth of the osseous system. Excessive height in young persons, and increase in the size of the facial bones or those of the extremities in adults, follow this hypertrophy of the gland. The lack of this secretion results in infantilism and corpulency, with subnormal temperature.

The Pineal Body or Epiphysis.—This is a very small body which seems to grow to its largest size at about the seventh year, thereafter, gradually lessening and becoming fibrous instead of glandular.

Its secretion seems to cause a lowering of blood-pressure and a lessening of the rate of development of the reproductive organs.

Pathological conditions of the pineal gland apparently result in obesity and too early sexual development. The ancients credited it with being the seat of the human soul. It is located on the under surface of the brain.

The Gonads.—These organs, the testis in the male and the ovary in the female produce a secretion from the so-called "interstitial" cells of Leydig. This is necessary to the development of the secondary sexual characteristics. There are also close relations between these secretions and those of other glands that influence nutrition.

Indeed, the testicular and ovarian secretions are believed to have a strong influence on the normal general development of body and mind.

The *primary sexual characteristics* are the ability to develop spermatozoa in the boy, and of ova in the girl, through the maturing of the organs concerned.

The *secondary sexual characteristics*, the changes that are outwardly visible, as, in the boy the deepening of the voice through changes in the larynx, the growth of hair on the face and about the generative organs, and the development of sexual desire.

In the girl the growth of the breasts, the widening of the pelvis, the growth of hair about the generative organs and menstruation are the secondary sexual characteristics.

QUESTIONS.

What is an "internal secretion"?

What is the "endocrine system"?

Describe the function of the thyroid gland. What conditions result from a deficiency of its secretion? From an excess?

Describe the functions of the adrenal glands.

Describe the functions of the gonads.

Describe the functions of the spleen.

CHAPTER XVI.

THE REPRODUCTIVE SYSTEM.

A NEW-BORN child has essentially the organs and structure of an adult being. But, there are certain deficiencies of development which are supplied as time goes on.

The first set of teeth has been mostly acquired by the end of the second year. The fontanelles of the skull have closed, and the organs of speech and of locomotion have begun to function by that same time. Very evident development of the intellectual centers has occurred, as well as a great increase in the size of the organism.

The replacement of cartilaginous material by bone, and the attainment of their full size by various bones, will occupy the years up to twenty. Growth and development proceed, more or less perfectly according to its heredity, the balance of the hormones, and the environment of the child.

But, up to the age of puberty, it is incapable of reproducing its kind. The object of its preservation and growth, according to the plan of Nature, is not achieved.

The term *puberty* indicates that time when the male child can produce *spermatozoa* and the female child can produce *ova*.

In the temperate clime this occurs from about the twelfth to the fourteenth year, and its onset is characterized by various changes in the body.

In the boy there is the deepening of the voice, the development of hair about the genitals and in the axillæ and a more rapid rate of growth. Indications of a coming beard are evident, as well as psychic changes in the personality.

In the girls the mammæ become rounded and fuller, the hips broaden, a growth of hair occurs in the axillæ and about the genitals, more rapid growth takes place and menstruation is established.

These are the signs of puberty that show the passing of childhood and the oncoming of adolescence. The hormones of the anterior pituitary gland are supposed to be responsible for these developments.

For the creation of a new individual an ovum must be fertilized by a spermatozoön, and then nourished for a period of some two hundred and eighty days. This implies *male and female organs of reproduction.*

These are, in the male, the testicles, the vasa deferentia, the

vesiculæ seminales and the penis. The testicles, lying in the scrotum, have innumerable tubules, the seminiferous tubules, lined with epithelial cells. From these cells arise spermatozoa, which swim in the fluid called semen. Semen is the secretion of the testicles, the vesiculæ seminales and the prostate gland.

The spermatozoa are sent out of the testicles through the vasa deferentia, into the urethra and the penis.

To fulfil their function the spermatozoa must meet and fertilize an ovum.

The female reproductive organs are the vagina, the uterus, the ovaries and the Fallopian tubes. These are contained within the true pelvis and communicate with the outside by means of the vagina.

The *vagina* is a canal, partly muscular, partly membranous, that opens at the surface of the perineum and surrounds the neck of the uterus.

The *uterus*, suspended midway in the pelvis by the broad ligament and the round ligaments is a pear-shaped hollow muscular organ, about $2\frac{1}{2}$ inches long. The cavity inside communicates through the cervix (neck) with the vagina below, and with the Fallopian tubes above.

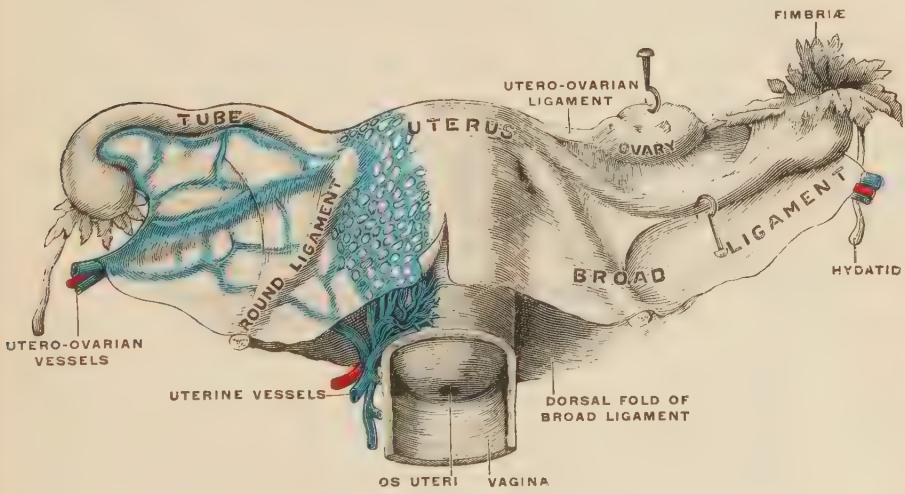


FIG. 308.—The uterus and appendages, front view. On the left side the tube is pulled down, the ovary lifted up. (Testut.)

The function of the uterus is to receive and contain the fertilized ovum, and provide for its nutrition and growth, with its eventual expulsion.

The two ovaries have the appearance of almonds imbedded in the broad ligament.

Their active elements are the Graafian follicles, which mature and extrude every twenty-eight days or so, an *ovum*. Between the follicles are the *interstitial cells*.

While the follicles are present at birth, they do not become functionally active until puberty. Their activity ceases at about the fiftieth year.

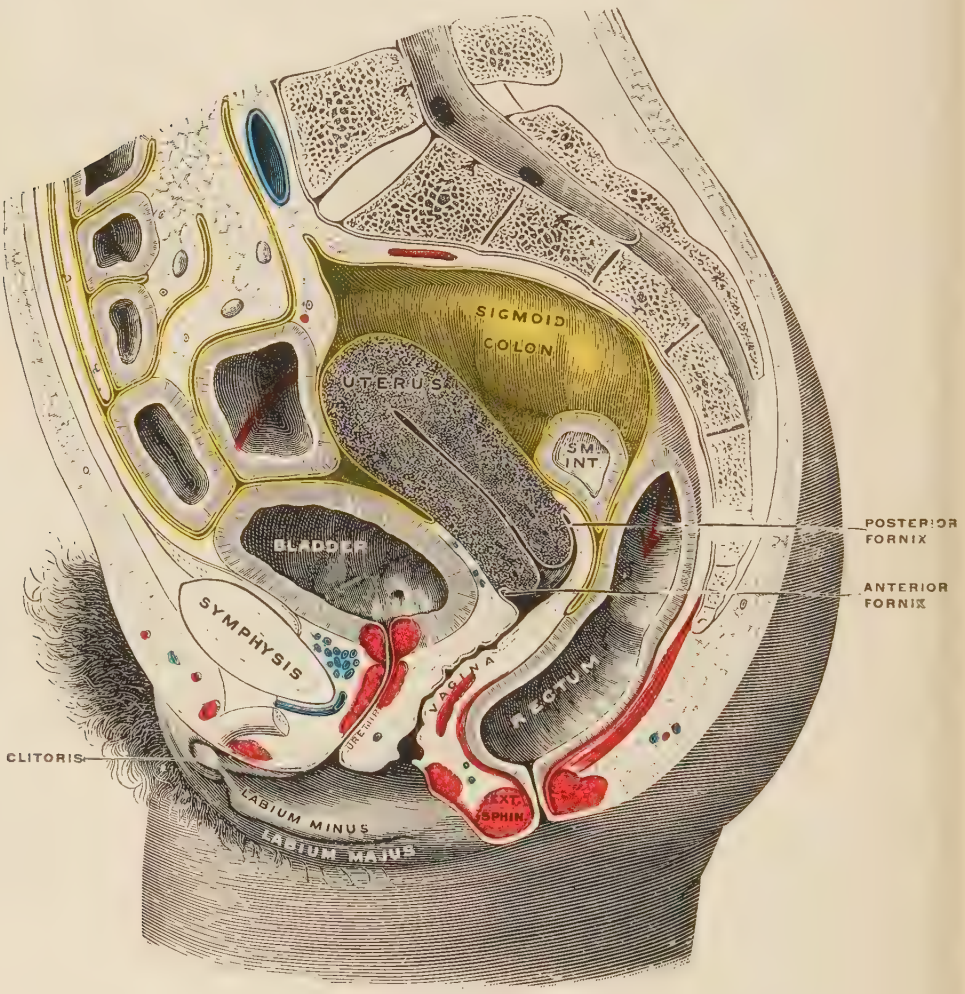


FIG. 309.—Sagittal section of the lower part of a female trunk, right segment. SM. INT., small intestine. (Testut.)

The *Fallopian tubes* lie on the upper border of the broad ligament. One end opens into the cavity of the uterus, the other, with moving, fringe-like processes, into the abdominal cavity. As the

ova are cast off from the surface of the ovary, they may be caught by these fringes, carried up into the tubes and thence into the uterus. This process is effected by the cilia on the mucous lining of the tube, which always wave toward the uterus.

If no spermatozoa are met during this journey the ovum is not fertilized, but is washed out of the uterus by the ensuing menstrual flow.

Menstruation.—This is a periodic bloody flow, which has been variously interpreted. The most satisfactory theory is that it so roughens the inner wall of the uterus that the fertilized ovum will be caught on it and have the chance to develop a new organism. The rhythmical ovulation and menstruation continue from puberty to the *menopause* (about the fiftieth year), when both stop. This provides for the mother, after the birth of the last possible child, an "expectancy of life" sufficiently long for the child to mature and become able to care for himself.

Pregnancy.—If the ovum meets a spermatozoön, either in the tube or ovary, it may be fertilized and pregnancy will result.

The spermatozoa consists of a cone-shaped head, a short straight rod-like body and a long filament-like tail. The head contains a nucleus of chromatin substance in which the hereditary characteristics are lodged.

These bodies are exceedingly active, and after being emitted in the act of sexual intercourse, swim into the uterus and tubes, retaining their vitality for more than a week.

The *ovum* is spherical, some 0.3 mm. in diameter. It is a mass of cytoplasmic material having a nucleus and a nucleolus. Around the cytoplasm is a clear ring, and that is surrounded by a layer of columnar epithelial cells.

Following the union of the two cells, the fertilized ovum goes into the uterus, settles on the mucous membrane and begins to grow. (For details of development, consult a text on embryology.)

At the end of about two hundred and eighty days the uterus has grown enormously, having left the pelvis and gone into the abdomen.

By contractions of the uterine muscles the fully-developed child passes outward, and takes its first breath. This initiates the life of a new individual.

Specialized development of the mammary glands provide milk for its nourishment during the most of the first year.

INDEX.

A

Abdominal aorta, 282, 290
cavity, organs within, 333
regions of, 333
Abduction defined, 112
Abductor hallucis muscle, 186
minimi digiti pedis muscle, 186
pollicis muscle, 165
Absorption, 350
Accessorius ad ilio-costalem muscle, 190
Accommodation, 263
Acetabulum, 91
Acromion, 78
Adduction defined, 112
Adductor brevis muscle, 170
gracilis muscle, 171
longus muscle, 170
magnus muscle, 169
pectineus muscle, 173
pollicis muscle, 165
Adenoid vegetations, 305
Afferent nerves, 233
Alimentary canal, 325
Alveoli, 308
Amino-acids, 338
Amœba, 27
Amphiarthrodial joints, 111
Anabolism, 359
Anatomical neck of humerus, 80
position, 20
Anatomy defined, 17
animal, 17
applied, 20
artistic, 20
descriptive, 20
microscopical, 20
pathological, 20
regional, 20
relational, 20
surgical, 20
systematic, 20
Anconeus, 152
Ankle-joint, movements of, 130
Annular ligament of ankle, 218
of wrist, 217
Anterior crural nerve, 259
interosseous nerve, 251
nares, 267
tibial artery, 286
Anterior tibial nerve, 260
ulnar vein, 291
Anus, 351
Aorta, 281
abdominal, 283
divisions of, 281
thoracic, 282
Aortic valve, 274
Aqueous humor of eye, 262
Arachnoid membrane of brain, 222
of spinal cord, 238
Arch, longitudinal, of foot, 109
palmar, 289
plantar, 286
transverse, of foot, 110
Arterial recoil, 297
tension, 297
Arterioles, 276
Artery, anastomosing branches of, 275
anatomy of, 274
anterior tibial, 286
aorta, 281
articular branches of, 275
axillary, 287
basilar, 287
brachial, 289
brachio-cephalic, 281
bronchial, 290
cœliac axis, 290
common carotid, 286
iliac, 283
coronary, 281
deep branches of, 275
divisions of, 275
external carotid, 286
iliac, 284
femoral, 284
gastric, 290
hepatic, 290
inferior mesenteric, 290
innominate, 281
intercostal, 290
internal carotid, 286
iliac, 284
mammary, 287
lumbar, 290
nutrient branches of, 275
œsophageal, 290
ovarian, 290
pericardial, 290
phrenic, 290

Artery, plantar arch, 286
popliteal, 284
posterior tibial, 286
pulmonary, 280
radial, 289
recurrent branches of, 275
renal, 290
splenic, 290
subclavian, 287
subcostal, 287
superficial branches of, 275
superior intercostal, 290
mesenteric, 290
suprarenal, 290
thyroid axis, 287
ulnar, 289
vertebral, 287
Arthrodia, 112
Articular process of vertebra, 63
Articularis genu muscle, 176
Articulations, 111
ankle, 130
atlas and axis, 115
carpo-metacarpal, 122
hip, 123
knee, 126
lower extremity, 123
medio-tarsal, 133
metacarpo-phalangeal, 122
occipito-atlantal, 115
pelvic, 123
phalangeal, 122, 133
radio-ulnar, 122
scapulo-clavicular, 117
shoulder-joint, 118
sterno-clavicular, 116
sternum and ribs, 115
tarsal, 131
thorax, 115
tibio-fibular, 130
of upper extremity, 116
of vertebral column, 112
articular processes, 113
bodies, 112
laminæ, 113
spinous processes, 113
transverse processes, 113
Aspera, linea, 98
Association function of cord, 243
Astragalus, 108
Atlas, 63
Auditory nerve, 265
Augmentation in cord, 243
Auricles of heart, 271
Auricular surface of ilium, 94
of sacrum, 69
Automatic action of cord, 244
Autonomic nervous system, 374
Axillary artery, 287
Axis, 64
Axis-cylinder process, 50
Axone, 50
Azygos veins, 290

B

Ball and socket joint, 112
Basal metabolism, 360
Basement membrane, 39
Basilar artery, 287
Basilic vein, 292
Biceps muscle, 149
flexor cruris muscle, 174
Bicipital tuberosity of radius, 90
Bile, 343
Bladder, gall, 347
urinary, 369
Blood, 52
as a carrier, 302
clotting of, 302
color of, 52
composition of plasma of, 52
distribution of, in body, 299
dust, 54
quantity of, in body, 299
supply of brain, 237
temperature of, in liver, 52
Body, temperature of, 363
of vertebra, 63
Bone and Bones, 35, 57
animal matter in, 36
canaliculi in, 36
cancellous, 35
carpal, 91
clavicle, 77
compact, 35
earthy matter in, 36
ethmoid, 60
femur, 96
fibula, 102
frontal, 59
hip, 91
hyoid, 75
ilium, 91
inferior maxillary, 61
ischium, 94
lachrymal, 61
lacunæ in, 36
lamellæ in, 36
malar, 61
mandible, 61
markings of, 58
metacarpal, 91
metatarsal, 109
mineral matter in, 36
nasal, 61
occipital, 59
os innominatum, 91
palate, 61
parietal, 59
periosteum of, 38
pubic, 95
radius, 90
recent, 36
scapula, 78
shapes of, 57
sphenoid, 60

Bone and Bones, superior maxillary, 61
tarsal, 108
temporal, 59
thigh, 96
tibia, 100
turbinated, 62
ulna, 84
vomer, 62
Brachial artery, 289
plexus, 249
Brachialis muscle, 150
Brachio-cephalic artery, 281
Brachio-radialis muscle, 152
Brachium, 80
Brain, 221
Bronchi, 307
Bronchial artery, 290
Bronchioles, 308
Brunner's glands, 342
Buccinator muscle, 200
Burdach's column, 241
Bursa acromialis subcutanea, 215
bicipitis cruris, 216
bicipito-radialis, 215
condylii externi, 216
interni, 216
infrapatellaris, 216
malleoli externi subcutanea, 216
interni subcutanea, 216
olecrani subcutanea, 215
poplitei, 216
postcalcanea profunda, 216
prepatellaris subcutanea, 216
pretibialis, 216
sartorii, 216
semimembranosi, 216
subacromialis, 215
suprapatellaris, 216
tibialis interna, 216
trapezii, 215
Bursæ, 215
Bursal synovial membrane, 41

C

Calcaneum, 108
Calories, 357
Calyces of kidneys, 366
Canaliculi, 36
Capillaries, anatomy of, 276
pulmonary, 279
systemic, 279
Capitellum, 84
Carbohydrate metabolism, 361
Carbohydrates, 355
Carbonate of soda, 343
Cardiac cycle, 96
muscle tissue, 50
orifice, 334
Carpus, 91
Carrier organs of body, 23
Cartilage, hyaline, 35
Cartilage, permanent, 35
temporary, 35
white fibro-, 35
yellow elastic, 35
Cauda equina, 238
Cavity of pelvis, 95
Cell or Cells, 26
aggregation of, 28
assimilation, 323
cardiac muscle, 50
ciliated epithelial, 40
columnar, 39
differentiation of, 28
glandular, 40
muscle, 45
nerve, 50
pigment, 40
polyhedral, 40
shape of, 27
striated muscle, 45
unstriped muscle, 49
Cellulose, 359
Central canal of cord, 239
fissure, 225
Cerebellum, 228
functions of, 236
Cerebral cortex, 224
fissures, 225
hemispheres, 223
lobes, 225
work, 237
Cerebrospinal fluid, 222
nerves, 245
Cerebrum, 223
functions of, 231
Cervical plexus, 249
branches of, 249
Cervicales ascendans muscles, 190
Chemical changes in muscle, 137
Chordæ tendineæ, 274
Choroid, 262
Chyle, 344
Chyme, 338
Circulation in brain, 237
Compressor nares, 200
Conditional reflexes, 234
Condyle, external, 81
internal, 81
Condyloid joints, 112
Conjunctiva, 263
Contraction, latent period, 47
of muscle, 47
Coördination in spinal cord, 243
Coraco-brachialis muscle, 147
Coracoid process, 78
Cornea, 262
Coronal plane, 20
Coronary artery, 281
Coronoid fossa, 81
Corrugator supercilii muscle, 202
Corpus callosum, 226
Corpuscles, red, 54
white, 55

Cortex, 224
functions of, 231
Cotyloid ligament, 124
Cranial nerves, 261
abducent (6), 261
auditory (8), 238, 261
facial (7), 261
glosso-pharyngeal (9), 261
hypoglossal (12), 262
motor-oculi (3), 261
olfactory (1), 261
optic (2), 261
pneumogastric (10), 261
spinal accessory (11), 262
trifacial (5), 261
trochlear (4), 261
vagus (10), 262
reflexes, 233
Crest of ilium, 94
of os pubis, 95
Cretinism, 383
Crossed pyramidal tract, 243
Cross-striped muscle, 45
Crypts of Lieberkühn, 341
Cuboid, 108
Cuneiform bones, 108
Curves of spine, 70
Cutis vera, 370
Cystic duct, 347

D

Decussation of pyramids, 231, 243
Deglutition, 332
Deltoideus muscle, 144
Dendrites, 50
Dentin, 38
Depressor alæ nasi muscle, 200
anguli oris muscle, 200
labii inferioris muscle, 200
Diaphragm, 196
Diarthrodial joint, 111
Diastole, 296
Diet, requisites of, 357
Digastricus muscle, 198
Digestion, chemical changes in, 323
organs concerned in, 325
Digestive system, 318
Direct pyramidal tract of cord, 243
Dorsal interossei muscle, 161, 186
Duct, Santorini's, 348
Ductus communis choledochus, 347
Duodenum, 341
Dura of brain, 221
of cord, 238
Dyspnea, 312

E

Ear, 265
external, 265
Ear, external, auditory meatus, 265
internal, 265
middle, 266
ossicles of, 266
Efferent nerves, 233
Elbow-joint, ligaments of, 120
movements of, 121
Encephalon, 221
Endocardium, 274
Ensiform cartilage, 70
Enzymes, 323
amylase, 324
amylolytic, 324
coagulating, 324
erepsin, 324
invertase, 324
lactase, 324
lipase, 324
lipolytic, 324
liver glycogenase, 324
maltase, 324
muscle glycogenase, 324
pepsin, 324
proteolytic, 324
ptyalin, 324
rennin, 336
steapsin, 324, 343
sugar splitting, 324, 343
trypsin, 324, 343
Epidermis, 373
Epiglottis, 305
Epinephrin, 384
Epiphysis, 385
Epithelial membrane, 40
Equilibrium, nitrogenous, 357
Erector spinæ muscle, 188
Erythrocytes, 54
Esophageal artery, 290
Esophagus, 332
Ethmoid, 60
Eupnœa, 312
Eustachian tube, 266
Exchange of O and CO_2, 316
Excretion, 365
Expiration, active, 312
passive, 312
Extension defined, 112
Extensor brevis digitorum muscle, 186
pollicis muscle, 164
carpi radialis brevis muscle, 156
longus muscle, 156
ulnaris muscle, 156
communis digitorum muscle, 160
indicis muscle, 160
longus digitorum muscle, 185
pollicis muscle, 165
minimi digiti muscle, 160
ossis metacarpi pollicis muscle, 164
proprius hallucis muscle, 185
External anterior thoracic nerve, 251
carotid artery, 286
iliac artery, 284
jugular vein, 290

External plantar nerve, 260
saphenous vein, 293
Eye, 262

F

Falciform lobe, 225
Falx cerebelli, 221
cerebri, 221
Fascia, 216
lata, 217
palmar, 217
plantar, 220
superficial, 217
Fats, 322
Femoral artery, 284
Femur, 96
Fenestra ovalis, 266
Fibrinogen, 302
Fibula, 102
Filum terminale, 238
Fissure, central, 225
longitudinal, 225
parieto-occipital, 225
Rolandic, 225
Sylvian, 225
Fissures of cord, 238
Flexion defined, 112
Flexor accessorius muscle, 183
brevis digitorum muscle, 184
hallucis muscle, 182
minimi digiti muscle, 160
pedis muscle, 184
pollicis muscle, 164
carpi radialis muscle, 154
ulnaris muscle, 154
longus digitorum muscle, 182
hallucis muscle, 181
pollicis muscle, 164
ossis metacarpi minimi digiti muscle, 160
pollicis muscle, 164
profundus digitorum muscle, 157
sublimis digitorum muscle, 157
Food purveyors of body, 22
Foods, carbohydrates in, 357
classes of, 321
fats in, 357
mineral salts in, 319
proteins in, 320
vitamines in, 358
water in, 319
Foot, 108
Fossa, glenoid, of scapula, 78
Framework of body, 22
Frontal bone, 59
lobe, 225
plane, 20
Frontalis muscle, 202
Functions of cord, 242

G

Gall-bladder, 347
Ganglia, inferior cervical, 375
Ganglia, middle cervical, 375
prevertebral, 376
sporadic, 376
superior cervical, 375
Ganglion impar, 375
Gastric artery, 290
digestion, 336
juice, 336
Gastrocnemius muscle, 177
Gemellus, inferior and superior, muscles, 173
General circulation, 280
Genio-hyoid muscle, 200
Ginglymus joints, 112
Girdle, pelvic, 95
shoulder, 76
Gladiolus, 70
Glands, 41
accessory to digestive tract, 325
adrenal, 384
Brunner's, 342
compound, 45
ductless, 381
endocrine, 382
gastric, 336
internal secretion of, 381
parathyroid, 383
parotid, 329
pineal, 385
pituitary, 384
racemose, 45
salivary, 329
sebaceous, 373
solitary, 341
sublingual, 329
submaxillary, 329
sweat, 372
thymus, 384
thyroid, 382
tubular, 44
Glandular tissue, 40
Glomerulus, 366
Glottis, 305
effect of closing in expiration, 307
in inspiration, 307
Gluteal lines, 94
ridge, 97
Gluteus maximus muscle, 166
medius muscle, 168
minimus muscle, 168
Glycogen, 347
Gonads, 385
Grammeter, 362
Gray matter of cord, 239
nervous tissue, 50
Great sciatic nerve, 260
Gustatory nerve, 261

H

Hair, 372
Heart, anatomy of, 271

Heart, apex beat of, 297
auricles of, 271
innervation of, 300
steadying output of, 297
valves of, 273
ventricles of, 271
Hemispheres, cerebral, 223
Hepatic artery, 290
duct, 347
vein, 290
Hilum of kidney, 366
Hip-joint, capsular ligament of, 124
ilio-femoral band of, 124
ligamentum teres of, 124
movements of, 126
"Y" ligament of, 124

I

Ileum, 338
Iliac crest, lips of, 94
Iliacus muscle, 166
Ilio-costalis muscle, 190
Ilio-hypogastric nerve, 257
Ilio-inguinal nerve, 257
Ilium, 91
Impar, ganglion, 375
Inferior maxillary bone, 61
mesenteric artery, 290
turbinated body, 305
Infraspinatus muscle, 149
Infundibulum, 346
Inguinal canal, 194
Innominate artery, 281
Inscription, tendinous, 46
Inspiration, 312
forced, 312
Insula, 225
Insulin, 349
Intercellular spaces, 278
substance, 28
Intercostal artery, 290
Intercostalis externi muscle, 197
interni muscle, 197
Internal anterior thoracic nerve, 251
carotid artery, 286
cutaneous nerve, 251
iliac artery, 284
jugular vein, 290
mammary artery, 287
plantar nerve, 260
saphenous vein, 293
Interossei dorsalis pedis muscle, 186
plantaris muscle, 180
Interstitial cells of Leydig, 385
Intertrochanteric lines, 97
Intervertebral disks, 112
foramina, 63
Intestinal digestion, 342
juice, 343
Intestine, large, divisions of, 350
small, movements of, 343
Intra-abdominal pressure, 313
Intrapulmonary pressure, 313
Intrathoracic pressure, 313
Iris, 262
Ischium, 94

J

Jejunum, 338
Joints, amphiarthrodial, 111
diarthrodial, 111
synarthrodial, 111
Juice canals, 278

K

Katabolism, 359
Kidneys, anatomy of, 365
location of, 365
nerve supply of, 369
Kinesthetic sense, 268
Kinetic urge, 382
Knee-joint, bursæ of, 129
ligaments of, 126
synovial membrane of, 126

L

Lachrymal bone, 61
duct, 263
gland, 263
Lacteals, 344
Lacunæ, 36
Lamellæ, 36
Laminæ of vertebræ, 63
Langerhans, islands of, 349
Laryngo-pharynx, 305
Larynx, 305
Latissimus dorsi muscle, 147
Lens, crystalline, 262
Lesser internal cutaneous nerve, 251
Leukocytes, 55
Levator anguli oris muscle, 200
costarem muscle, 197
labii inferioris muscle, 200
superioris alaquæ nasi muscle, 200
proprius muscle, 200
scapulæ muscle, 142
Leydig, interstitial cells of, 385
Ligament, alar, of knee, 129
annular, of ankle, 218
of wrist, 217
capsular, of shoulder, 118
coronary, of knee, 126
cotyloid, 124
crucial, 126
gleno-humeral, 119
ischio-femoral, 126
mucosa, of knee, 129
orbicular, 122

Ligament, patellar, 126
plantar, 133
Poupart's, 193
pubo-femoral, 124
teres, 124
transverse, of knee, 126
Winslow's, 126
Limbic lobe, 225
Linea alba, 194
Liquid tissue, 52
Liver, lobes of, 345
Lobes, caudatus, 345
cerebral, 225
falciform, 225
frontal, 225
insula, 225
limbic, 225
occipital, 225
parietal, 225
quadratus, 345
Spigelii, 345
temporal, 225
Lobules of liver, 345
Lobulettes, 309
Long saphenous vein, 293
subscapular nerve, 251
Longissimus dorsi muscle, 190
Longus colli muscle, 200
Lymph, 53, 301
nodes, 301
nodules, 341
radicles, 301
spaces, 278
work of, 301

M

Malar bone, 61
Malleolus, external, 108
internal, 101
Malpighian corpuscle, 367
Mandible, 61
Manubrium, 70
Masseter muscle, 202
Master organs of the body, 24
Mastication, 328
Median basilic vein, 292
cephalic vein, 291
nerve, 251
vein, 292
Mediastinum, 309
Medio-tarsal joint, 133
Medulla oblongata, 229
Membrana tympanum, 266
Membranes, 39
arachnoid, 222, 238
Schneiderian, 267
Meninges of brain, 222
of cord, 238
Menstruation, 389
Mesial, 20
Metabolism, 359
Metacarpal bones, 91
Metatarsal bones, 109
Middle turbinated body, 267
Mind, subconscious, 380
Mineral salts in body, 319
Mitral valve, 274
Motor centers of brain, 232
Mouth, 325
Movements of foot, 133, 165
of leg, 165
of segments of upper extremity, 139
of shoulder, 139
of spinal column, 114
of thigh, 165
of toes, 166
Muscle or Muscles, 135
abductor hallucis, 186
minimi digiti pedis, 186
pollicis, 165
accessorius ad ilio-costalem, 190
adductor brevis, 170
gracilis, 170
longus, 170
magnus, 169
pectineus, 173
pollicis, 165
anconeus, 152
articularis genu, 176
biceps, 149
flexor cruris, 174
brachialis, 150
brachio-radialis, 152
buccinator, 200
cervicales ascendens, 190
complexus, 191
compressor nares, 200
contraction of, 47
coraco-brachialis, 147
corrugator supercilii, 202
deltoideus, 144
depressor alæ nasi, 200
anguli oris, 200
labii inferioris, 200
diaphragm, 196
digastricus, 200
direct action of, 137
erector spinæ, 188
of expression, 200
extensor brevis digitorum, 186
pollicis, 164
carpi radialis brevis, 156
longus, 156
ulnaris, 156
communis digitorum, 160
indicis, 160
longus digitorum, 185
pollicis, 165
minimi digiti, 160
ossis metacarpi pollicis, 164
proprius hallucis, 185
of eyeball, 264
flexor accessorius, 183

Muscle or Muscles, flexor brevis digitorum, 184
hallucis, 182
minimi digiti, 160
pedis, 184
pollicis, 164
carpi radialis, 154
ulnaris, 154
longus digitorum, 182
hallucis, 181
pollicis, 164
ossis metacarpi minimi digiti, 160
pollicis, 164
profundus digitorum, 157
sublimis digitorum, 157
frontalis, 202
gastrocnemius, 177
gemelli, 173
genio-hyoid, 200
gluteus maximus, 166
medius, 168
minimus, 168
grouped according to function, 202
iliacus, 166
ilio-costalis, 190
infraspinatus, 149
insertion of, 136
intercostales externi, 197
interni, 197
interossei dorsalis, 161
pedis, 186
palmaris, 161
plantaris, 186
latissimus, 147
levator anguli oris, 200
costarem, 197
labii inferioris, 200
superioris alæque nasi, 200
proprius, 200
scapulæ, 142
as levers, 136
longissimus dorsi, 190
lumbricales, 160, 184
multifidus spinæ, 191
mylo-hyoid, 200
naming of, 138
obliquus capitis inferior, 192
superior, 192
externus abdominis, 193
internus abdominis, 194
obturator externus, 173
internus, 173
occipitalis, 202
omo-hyoid, 200
orbicularis oris, 200
palpebrarum, 202
origin of, 136
palmaris longus, 154
pectoralis major, 146
minor, 144
peroneus brevis, 181
Muscle or Muscles, peroneus longus, 180
tertius, 177
plantaris, 180
platysma, 200
popliteus, 175
pronator quadratus, 152
teres, 152
psoas magnus, 166
pterygoideus externus, 202
internus, 202
pyramidalis, 192
nasi, 200
pyriformis, 173
quadratus femoris, 173
lumborum, 196
quadriceps extensor cruris, 175
rectus abdominis, 192
capitis anterior major, 200
minor, 200
lateralis, 200
posterior major, 192
minor, 192
femoris, 175
reversed action of, 137
rhomboideus major, 143
minor, 143
risorius, 200
rotatores spinæ, 191
sartorius, 174
scalenus anterior, 198
medius, 198
posterior, 198
semimembranosus, 174
semispinalis capitis, 191
cervicis, 191
dorsi, 191
semitendinosus, 174
serratus magnus, 144
posterior inferior, 187
superior, 187
soleus, 177
spinalis dorsi, 190
splenius capitis, 187
cervicis, 187
sterno-hyoid, 200
sterno-mastoideus, 199
sterno-thyroid, 200
stylo-hyoid, 200
subclavius, 144
subcostales, 197
subscapularis, 149
supinator, 154
supraspinatus, 145
temporalis, 202
tensor fascia lata, 167
tarsi, 202
teres major, 148
minor, 149
thyro-hyoid, 200
tibialis anterior, 177
posterior, 177
trachelo-mastoid, 190

Muscle or Muscles, transversalis abdominis, 195
cervicis, 190
trapezius, 141
triangularis sterni, 197
triceps, 152
vastus externus (lateralis), 175
intermedius, 175
internus (medialis), 175
zygomaticus major, 200
minor, 200
Muscular coat of small intestine, 339
of stomach, 335
sense, 268
Musculo-cutaneous nerve, 251, 260
Musculo-spiral nerve, 257
Mucous coat of small intestine, 339
of stomach, 336
membrane, 40
Multifidus spinæ muscle, 191
Myelon, 238
Mylo-hyoid muscle, 200
Myxodema, 383

N

Nails, 373
matrix of, 373
Nares, posterior, 267
Nasal bones, 61
Naso-pharynx, 305
Neck, surgical, of humerus, 80
Nerve cell, 50
Nerves, afferent, 233
anterior crural, 259
interosseous, 251
tibial, 260
auditory, 265
circumflex, 256
efferent, 233
external anterior thoracic, 251
plantar, 260
great sciatic, 260
gustatory, 261
ilio-hypogastric, 257
ilio-inguinal, 257
internal anterior thoracic, 251
cutaneous, 251
plantar, 260
lesser internal cutaneous, 251
long subscapular, 251
median, 251
musculo-cutaneous, 251, 260
musculo-spiral, 257
obturator, 259
olfactory, 267
peroneal, 260
popliteal, 260
posterior interosseous, 257
thoracic, 251
tibial, 260
radial, 257
Nerves of special sense, 262
splanchnic, 377
suprascapular, 251
of touch, 268
ulnar, 256
vaso-constrictors, 299
vaso-dilators, 299
vaso-motor, 300
Nervous tissue, 50
Neural arch, 63
Neurilemma, 50
Neuron, 50
Nose, 267, 304
Nuchæ, ligamentum, 113

O

Obliquus capitis inferior muscle, 192
superior muscle, 192
externus abdominis muscle, 193
internus abdominis muscle, 194
Oblongata, 229
Obturator externus muscle, 173
foramen, 94
internus muscle, 173
nerve, 259
Occipital bone, 59
lobe, 225
Occipitalis muscle, 202
Odontoid process of axis, 64
Œsophageal artery, 290
Olecranon, 84
Olfactory nerve, 267
Omentum, 335
Omo-hyoid muscle, 200
Orbicularis oris muscle, 200
palpebrarum muscle, 202
Organs of motion, 23
Oro-pharynx, 305
Os innominatum, 91
pubis, 95
Ossicles of ear, 266
Ovarian artery, 290

P

Pacinian corpuscles, 370
Palate bones, 61
Palmar arches, 289
fascia, 217
interossei muscles, 161
Palmaris longus muscle, 154
Pancreas, 347
Pancreatic juice, 348
Parietal bones, 59
lobe, 225
Parieto-occipital fissure, 225
Parotid glands, 329
Patella, 99
Pectoralis major muscle, 146
minor muscle, 144

Pedicles, 63
Pelvic cavity, 96
girdle, 96
Pelvis, 95
contents of, 96
of kidneys, 366
Pepsin, action of, 337
Peptone, 338
Pericardial artery, 290
Pericardium, 271
Periosteum, 38
Peripheral resistance, 298
Peristalsis, 343
Peritoneum, 339
Perivascular spaces, 278
Peroneal nerve, 260
Peroneus brevis muscle, 181
longus muscle, 180
tertius muscle, 178
Phagocytes, 55
Phalanges, 91, 109
Pharynx, 305
Phrenic artery, 290
nerve, 249
Physiology defined, 17
Pia of brain, 221
of cord, 238
Pivot joint, 112
Plain muscle tissue, 49
Plantar arches, 286
fascia, 220
Plantaris muscle, 180
Plasma, 52
Platelets, 55
Platysma muscle, 200
Pleura, parietal, 309
visceral, 309
Plexi of spinal nerves, 249
Pons Varolii. 228
Popliteal artery, 284
nerve, 260
notch, 100
Popliteus muscle, 175
Portal circulation, 290
vein, 290
Posterior interosseous nerve, 257
nares, 305
thoracic nerve, 251
tibial artery, 286
nerve, 260
ulnar vein, 291
Poupart's ligament, 193
Pregnancy, 389
Prehension, 323
Prevertebral ganglia, 376
Primary proteoses, 338
Processes in converting food, 323
Pronator quadratus muscle, 152
teres muscle, 152
Properties of a living body, 25
Protein metabolism, 360
Proteins, 321
Psoas magnus muscle, 166
Pterygoideus externus muscle, 202
internus muscle, 202
Puberty, 386
Pulmonary artery, 280
capacity, 315
capillaries, 281
circulation, 280
valve, 274
Pulse, 297
venous, 297
Pyloric orifice, 334
Pyramidal cells of cortex, 232
Pyramidalis muscle, 192
nasi muscle, 200
Pyramids of brain, function of, 232
decussation of, 230
Pyriformis muscle, 173

Q

Quadratus femoris muscle, 173
lumborum muscle, 196
Quadriceps extensor cruris muscle, 175

R

Radial artery, 289
nerve, 257
vein, 291
Radio-ulnar articulation, 122
Radius, 90
Rami of os pubis, 95
Ramus communicans, 245
of ischium, 94
Ranvier, nodes of, 52
Receptaculum chyli, 344
Reciprocal reception joint, 112
Recoil, arterial, 297
Rectum, 352
Rectus abdominis muscle, 192
capitis anterior major muscle, 200
minor muscle, 200
lateralis muscle, 200
posterior major muscle, 192
minor muscle, 192
femoris muscle, 175
Red corpuscles, 301
work of, 301
Reflex action of cord, 244
arc, 244
Reflexes, 233
conditional, 233
cranial, 233
spinal, 244
unconditional, 233
Relation of autonomic and cerebro-spinal systems, 374
system to body functions, 377
of parts of the body, 21
Renal artery, 290
circulation, 280

Rennin, action of, 336
Reproductive organs, 386
Residual air, 315
Respiration defined, 304
external, 304
internal, 304
mechanism of, 312
organs concerned in, 304
rate of, 313
ratio to pulse and temperature, 313
relation to abdominal functions, 314
to circulation, 313
rhythm of, 313
sounds of, 313
types of, 313
Respiratory movements, innervation of, 317
Retina, 262
Rhomboid ligament, 114
Rhomboideus major muscle, 143
minor muscle, 143
Ribs, 72
angle of, 73
floating, 72
sternal, 72
tubercle of, 72
vertebral, 72
Risorius muscle, 200
Rolandic fissure, 225
Rotation defined, 112
Rotatores spinæ muscles, 191

S

Saccule of ear, 266
Sacral plexus, 259
Sacro-iliac synchondrosis, 123
Sacrum, 66
Saddle joints defined, 112
Sagittal plane, 20
Saliva, 329
Sarcoplasm, 47
Sartorius muscle, 174
Scalenus anterior muscle, 198
medius muscle, 198
posterior muscle, 198
Scaphoid, 108
Scapula, 78
Schneiderian membrane, 267
Schwann, white substance of, 50
Sclerotic coat, 262
Sebaceous glands, 373
Secondary proteoses, 338
Secretion, 40
Semicircular canals of ear, 267
Skin, papillæ of, 370
Sleep, 238
Solar plexus, 376
Soleus muscle, 177
Solitary glands, 341
Special centers of cord, 244
Speech centers of brain, 232
Sphenoid, 60
Sphincter vesicæ muscle, 370
Spinal column, movements of, 114
cord, 238
association function of, 243
augmentation function of, 243
automatic function of, 244
Burdach's column of, 241
central canal of, 239
commissures of, 239
coördination in, 244
cornu of, 239, 240
crossed pyramidal tracts of, 243
direct pyramidal tracts of, 243
dura of, 238
fissures of, 238
functions of, 242
gray matter of, 239
meninges of, 238
reflex action of, 244
transference, function of, 243
white matter of, 242
foramen, 63
nerves, 245
plexi of, 249
reflexes, 244
Spinalis dorsi muscle, 188
Spine as a whole, 70
curves of, 70
Spinous processes of ilium, 91
of vertebræ, 63
Splanchnic nerves, 377
Spleen, 381
Splenic artery, 290
Splenius capitis muscle, 187
cervicis muscle, 187
Sporadic ganglia, 376
Sterno-hyoid muscle, 200
Sterno-mastoideus muscle, 200
Sterno-thyroid muscle, 200
Sternum, 70
Stomach, 334
coats of, 335
glands of, 336
greater curvature of, 334
lesser curvature of, 334
Stratum corneum, 373
lucidum, 373
Striated muscle tissue, 45
Stylo-hyoideus muscle, 200
Subclavian artery, 287
Subclavius muscle, 144
Subconscious mind, 380
Subcostal artery, 287
Subcostales muscle, 197
Sublingual glands, 329
Submaxillary glands, 329
Submucous coat of intestine, 339
of stomach, 336
Subscapularis muscle, 149
Succus entericus, 341

Suction pump of circulation, 298
Superficial veins, 291
Superior intercostal artery, 290
maxillary bone, 61
mesenteric artery, 290
turbinated body, 267
Supinator muscle, 154
Supplemental air, 315
Suprarenal artery, 290
capsules, 384
Suprascapular nerve, 251
Supraspinatus muscle, 145
Surgical neck of humerus, 80
Sustentaculum tali, 108
Sweat glands, 372
Sylvian fissure, 225
Sympathetic plexi, 376
Synarthrodial joints, 111
Synchondrosis, sacro-iliac, 123
Synovial fluid, 41
membrane, 41
Syntonin, 337
Systemic capillaries, 276
circulation, 280
Systole, 296

T

Tarsal joints, 131
Taste buds, 267
Teeth, 325
Temporal bone, 59
lobe, 225
Temporalis muscle, 202
Tendinous inscription, 46
Tensor fascia lata muscle, 167
tarsi muscle, 202
Tentorium cerebelli, 221
Teres ligament, 124
major muscle, 148
minor muscle, 149
Thermogenesis, 363
Thermolysis, 363
Thermotaxis, 363
Thoracic aorta, 290
Thorax, 74
normal position of, 312
Thrombin, 302
Thyro-hyoid muscle, 200
Thyroid, 382
axis, 287
foramen, 94
Tibia, 100
Tibialis anterior muscle, 177
posterior muscle, 177
Tidal air, 315
Tissue, adenoid, 34
adipose, 33
areolar, 32
cardiac, 50
cartilaginous, 35
connective, 30
Tissue, dentinal, 38
epithelial, 39
gelatinous, 34
glandular, 40
hyaline cartilage, 35
neuroglia, 34
osseous, 35
plain muscle, 49
striated muscle, 45
white fibro-cartilage, 35
fibrous, 31
yellow elastic, 32
fibro-cartilage, 35
Tongue, 267–329
Tonsils, 330
Trachea, 307
Trachelo-mastoideus muscle, 190
Transversalis abdominis muscle, 195
cervicis muscle, 190
Trapezius muscle, 141
Triangularis sterni muscle, 197
Triceps muscle, 152
Tricuspid valve, 273
Trochanter, great, 97
lesser, 97
Trochlear surface of humerus, 81
Tuberosities of humerus, 80
Tuberosity, bicipital, 90
of ischium, 94
Turbinated bodies, 62
Tubule, uriniferous, 367
Tympanum, 266

U

Ulna, 84
Ulnar artery, 289
nerve, 256
Unconditional reflexes, 233
Unstriated muscle, 49
Urea, 368
Ureters, 368
Urethra, 370
Urine, composition of, 368
Utricle of ear, 266
Uvula, 325

V

Vaginal synovial membrane, 41
Valves of heart, 273
of veins, 277
Valvulæ conniventes, 339
Vasa vasorum, 275
Vaso-constrictor nerves, 299
Vaso-dilator nerves, 299
Vaso-motor nerves, 300
Vastus externus (lateralis) muscle, 175
intermedius muscle, 175
internus (medialis) muscle, 175
Veins, anatomy of, 277

Veins, anterior ulnar, 291
azygos, 290
basilic, 292
deep, 290
external jugular, 290
saphenous, 293
general arrangement of, 290
hepatic, 290
internal jugular, 290
saphenous, 293
long saphenous, 293
median, 292
basilic, 292
cephalic, 292
portal, 290
posterior ulnar, 291
radial, 291
short saphenous, 293
superficial, 291, 293
of lower extremity, 293
of upper extremity, 291
systemic, 290
Venous pulse, 297
radicles, 279
Venule, 276
Vena cava, inferior, 290
superior, 290
Ventricles of brain, 222
of heart, 271
Vermiform appendix, 350
Vermix, 228
Vertebra, cervical, 63
dorsal, 65
lumbar, 65
prominens, 64
sacral, 66
thoracic, 65
Vertebra, typical, 62
Vertebral artery, 287
body, 63
groove, 70
Villi, 339
Vital capacity, 315
Vitamines in food, 358
Vitreous of eye, 262
Vocal cords, 307
Vomer, 62

W

Waste removers of body, 23
Water in body, 319
White corpuscles, 55
work of, 301
fibers of cord, 242
matter of cord, 239
nervous tissue, 50
substance of Schwann, 50
Wrist-joint, ligaments of, 122
movements of, 122

Y

Yellow elastic tissue, 32
fibro-cartilage, 35
"Y" ligament of Bigelow, 124

Z

Zygomaticus major muscle, 200
minor muscle, 200